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IN THIS ISSUE

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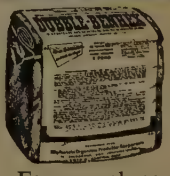

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DILUTIONS

Dipping: Establishment, 1 gal. to 100 gals. water. Replenishment, 1½ gals. to 100 gals. water.

Spraying: 1 gal. to 100 gals. water.

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(30% DDT Miscible Oil)

Cattle Dip and Spray: Kills all ticks *including the arsenic and BHC resistant Blue tick* (Boophilus decoloratus)! Kills flies and lice. Hi-D is a concentrated miscible oil and is especially recommended for the control of the resistant Blue Tick.

DILUTIONS

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Spraying: 1 *gal. to* 100 *gals. dipwash.*

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Readers are reminded that all agricultural inquiries, whether they relate to articles in the Journal or not, should be addressed to the local Director of Agriculture, and not to the Editor.

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NOTES ON ANIMAL DISEASES

XX—BREEDING DISEASES OF CATTLE*

Compiled by the Department of Veterinary Services, Kenya

(*Received for publication on 25th January, 1958*)

The previous article in this series on breeding diseases in cattle was written as recently as 1949, and it is a measure of the achievement of recent veterinary research that it has become necessary to rewrite these notes after so short a time as nine years. It is a measure also of the wisdom of the control measures advocated in the earlier article that, although we now know considerably more about the diseases which case infertility, the control measures which we advise to-day remain virtually unchanged.

Three specific infectious diseases cause the greater part of the infertility so widespread among cattle in Kenya. These diseases, "Epivag", Trichomoniasis and Vibriosis, are the subject of the three parts of this article.

"EPIVAG"

"Epivag" is the popular name of an infectious venereal disease of cattle, widespread in Kenya and other parts of Africa, which causes epididymitis in the bull and vaginitis in the cow and heifer. It is a disease which has not been intensively investigated, and our knowledge of it is practically limited to the observations of field workers.

One of the outstanding features of "epivag" is that high grade and European type cattle are extremely susceptible to infection, while indigenous Zebu stock only very rarely show signs of the disease. In general, the greater the proportion of indigenous blood in an animal's make-up the less likely it is to suffer from the clinical manifestations of "epivag". Further low grade and indigenous stock, both male and female, are apparently able to carry the infection and transmit it without themselves becoming clinically infected. It is generally accepted that such symptomless carriers are the usual means by which infection is introduced into clean herds.

The disease is undoubtedly caused by an infective agent, most probably a virus, but experimental work has not yet yielded conclusive proof of this. Transmission of infection takes place usually at coitus, though there are indications that insect-borne infection may occasionally occur.

The symptoms of the disease are characteristic and enable "epivag" to be dintinguished from other breeding diseases with a fair degree of certainty.

The Disease in the Bull

In the bull "epivag" produces changes in the shape, size and consistency of one or both testicles. The first appreciable change can usually be felt as a slight hardening and enlargement of the epididymis at the lower tip of the testicle when this is palpated through the scrotum. The normal epididymis is a small appendage which protrudes only very slightly below the testicle; its consistency is very little harder than that of the testicle, so that in the healthy animal it is only just possible to appreciate its presence by palpation. In the early stages of the disease, careful comparison of the two organs is useful in determining whether or not changes are present on either side. Later, the hardening and enlargement becomes very marked, and the changes in size and shape become easily visible without handling the testicle. Both organs are involved as the disease progresses, but the changes are usually more pronounced on one side than on the other. At post-mortem examination the changes are seen to consist of fibrosis and abscess formation involving the epididymis, while the true testicular tissue is reduced in size but is of normal appearance and consistency.

The course of the disease in affected bulls is remarkedly constant except that in some

*A revision of Notes on Animal Diseases XX, which appeared in this *Journal* Vol. 9, 1943, p. 116.

animals the changes are appreciable in as little as two months and pronounced in six months, while in others the lesions may take months or even years to appear.

It is important to consider the fertility of the infected bull. Changes occur in the semen very early in the disease—before, in fact, any appreciable changes are present in the testicle. There are chemical changes in the fluid part of the semen, while the sperm become reduced in number, abnormal in form, and eventually disappear altogether from the semen. Thus impaired fertility is one of the early features of the disease. When the damage to the epididymis reaches a certain stage, complete blockage of the spermatic duct occurs, and, if the condition is bilateral, sterility is complete. So long as the duct on one side remains open, the bull may still get calves, though by this time his fertility is invariably low.

It is important also to appreciate that the bull commences to disseminate infection very soon after becoming infected, and long before he himself shows any symptoms. There are in fact good grounds for believing that he is more highly infective at this preclinical stage than he is later, after lesions have appeared. The infected bull usually retains his willingness to serve throughout, so that even when completely sterile he is still capable of transmitting infection at coitus.

The Disease in the Cow

In the female the outstanding clinical feature of the disease is a cervico-vagnitis, i.e. inflammation of the anterior part of the vagina, extending into the cervix of the uterus. This results in a characteristic discharge from the vagina of a thick, tenaceous, yellowish, mucopurulent material. This discharge, or its dried up remnants, may often be seen on the tail below the level of the vulva, and on the hindquarters, where it has been spread by the tail. The amount of discharge varies with the individual cow, but in most infected herds, a number of animals can be found showing these characteristic "snail-tracks".

The incubation period in the female is quite short, probably between one and ten days. The first sign of disease is the cervicovaginitis with its accompanying discharge, and often the disease progresses no further than this. Sometimes, however, infection spreads forward into the uterus, or even further, involving the oviducts, and it may even reach the peritoneal cavity to cause peritonitis and death. While infection is present in the vagina or uterus, the resultant inflammation is sufficient to render the animal temporarily sterile.

It is not by any means certain what modifications, if any, occur in the oestral rhythm. Some observers believe that affected animals return to service after irregular intervals, and that a lapse of three to five months is common. It is not clear whether this suspension of oestrus, if in fact it occurs, represents an early interruption of pregnancy, such as occurs in trichomoniasis, or whether it is simply a state of disturbed oestral function. It also seems possible that the rhythm remains undisturbed but that it is masked by the manifestations of the disease itself. With copious outpouring of cervical and vaginal mucus, it is understandable that a female might fail to attract the bull and in any case, if served, would be most unlikely to conceive. Whatever the explanation, however, it is clear that in most cases a period of infertility occurs which is followed after some months by apparent recovery and resumption of normal breeding.

Unfortunately, not all infected females make a complete recovery; a proportion, which may be up to 20 per cent, remain permanently sterile. There is also a suggestion that some animals recover and resume normal breeding for two or even three years and then become sterile. Sterility is usually associated with extensive forward spread of the disease beyond the uterus and into the oviducts, where the inflammatory changes result eventually in complete occlusion of the ducts, effectively preventing conception.

There is a wide range in the severity of symptoms produced in the female. Cases may be seen in any outbreak varying between a transient vaginitis associated with only a brief disturbance in fertility and a severe progressive infection resulting in permanent sterility. There is, however, a normal or average response, so far as high grade cattle are concerned, consisting of a severe cervicovaginitis, often with severe secondary bacterial infection, followed by spontaneous resolution and a return to normal breeding within a few months' time.

The Disease in the Herd

The disease is usually first noticed when it becomes apparent that infertility is present in the herd. An examination then discloses

females with vaginitis and probably bulls with epididymitis. The pregnancy status of such a herd varies within wide limits; there may be few or a great many animals not pregnant. The incidence of infection also varies, but it often appears that all females served by an infected bull have acquired infection.

The high susceptibility of exotic cattle and high resistance of indigenous animals have already been mentioned. Besides these, however, other unknown factors must exist which determine the severity of the course that the disease will take in the individual herd.

Two extreme examples may be quoted of the type of disease outbreak occurring in Kenya; both outbreaks to be described were in high grade cattle. In the first case, involving a herd of 300 cattle, there was a severe outbreak of infertility following the introduction of a Zebu bull. The acute stage of the disease extended over some six months, after which fertility gradually improved with the introduction of artificial insemination. Complete sterility remained in a large proportion of infected females, and eventually almost 20 per cent of the adult stock were culled for this reason.

In the second case, a large herd was found to have been infected for a considerable number of years, but the disease was of an altogether milder character. There was very little evidence of vaginitis, and infertility among the females was insignificant; a few, about ten per cent in one year, returned once, twice or three times to the bull before settling safely in calf. In the bulls, specific lesions appeared only several years after initial infection. They remained clinically normal and fully fertile until after their useful breeding life in the herd was over. It was only, in fact, because the owner of this herd retired his old bulls to pasture that it was possible to diagnose the disease from the presence of lesions in every one of them.

Thus the severity of outbreaks of "epivag" varies considerably between different herds. It is fortunately true that the milder type of disease seems to be commoner than the acute.

Diagnosis

Diagnosis is based upon the presence of temporary infertility with associated vaginitis and typical vaginal discharge; there is usually also a history of recent introduction of native type stock, commonly a native bull. If, in addition, epididymitis is found in a high grade bull, there can be no doubt as to the presence of the disease. There are at present no laboratory methods of diagnosis beyond the pathological examination of the reproductive organs of the bull at post-mortem.

Treatment

There is no known effective treatment against the causative agent itself, but the secondary bacterial infection which frequently follows the initial vaginitis in the female can often be controlled to some degree by the use of the following douche:—

Common salt ..	8.5 grammes (2 oz.)
Neutral acriflavine	1.0 gramme (¼ oz.)
Water	1.0 litre (1½ gall.)

This should be run into the vagina (not the uterus) through a suitable tube at weekly intervals so long as the dischage persists.

Control and Eradication

The farmer whose herd is infected with "epivag" is faced with three distinct problems:—

(*a*) To restore maximum possible fertility to those animals already infected.

(*b*) To prevent infection from reaching animals not yet infected.

(*c*) To eradicate the disease.

By far the most effective method of achieving these objectives is the introduction of artificial insemination in place of natural breeding. Infected bulls must of course be eliminated; they cannot be cured and are usually of low fertility if not sterile. It has frequently been observed that cows can safely become pregnant even during the acute stage of an outbreak if served by a healthy bull or inseminated with healthy semen. Thus artificial insemination is the only way of improving fertility among infected animals without danger of further spread of the disease. In fact, it solves immediately the first two of the problems set out above.

The commonly adopted device of introducing a resistant bull (i.e. an indigenous Zebu type animal) must be mentioned here. This undoubtedly shortens the period of infertility in infected females, but does not prevent further spread of infection to healthy animals because the native bull carries the infection without himself contracting the disease. In a badly infected herd, the native bull may be

highly effective in restoring fertility. The drawback to this method, apart from the abrupt change in breeding policy, is that it results in spreading the infection until the whole herd is involved; it represents, indeed, a policy of living with the disease, which will remain in the herd for many years. Also future grading up in such a herd could only safely be by artificial insemination.

From the point of view of control of the disease, the advantages of exclusive artificial insemination over the introduction of a native bull are very evident.

The question of eradication, as distinct from control, of "epivag" is a very difficult one. It is bound up with the unsolved problems of immunity and the possibility of symptomless carriers among high grade stock. The opinion has often been expressed that once a cow carries a normal calf after being infected, she automatically "cleans herself" and becomes non-infective again. Against this, some clinicians believe that recovered animals can harbour the infection indefinitely, and of course pass it on at natural service. Neither view is supported by experimental evidence, nor are accurate clinical observations available to resolve the question. It is true that cases are known in Kenya where artificial insemination has been practised for a number of years (six years in one case) and then a reversion to natural breeding has been followed by the reappearance of the disease. Unfortunately, in such cases, it is virtually impossible to rule out entirely the possibility of reinfection. Nevertheless, it is certainly safer from the practical point of view to postulate that an infected animal is likely to remain a carrier for an indefinite period rather than that she becomes harmless as soon as she produces a calf. Supporting this view also is the undoubted fact that native cattle can become symptomless carriers; there seems no *a priori* reason why low grade cattle at any rate, and quite possibly higher grade animals, should not also attain the healthy carrier stage. In consequence, so long as our knowledge of these aspects of the disease remains incomplete, we must accept that eradication can only be achieved by the continued use of artificial insemination, until such time as all animals in the original infected herd have been eliminated.

Another device which finds frequent application in the control of breeding diseases should be mentioned, although it is of less value with "epivag" than with the other bovine venereal diseases. This consists of segregation of the herd into clean and infected groups (after removal of all infected bulls). In the clean group, natural breeding may be allowed with healthy bulls, and to the infected group are applied control measures as already described. In actual fact, segregation is not often possible in outbreaks of "epivag", partly because the disease has usually assumed extensive proportions before it is recognized, and partly because it most often occurs in herds where females run with the bull and the necessary segregation cannot be made with sufficient certainty. When used to control "epivag" segregation must be absolute, i.e. the groups must be maintained permanently as entirely separate herds and a high standard of supervision is necessary to ensure that no mistakes or accidents occur.

TRICHOMONIASIS

Note on the similarity between Trichomoniasis and Vibriosis

These two diseases are so very similar in many respects that it seems advisable to consider them briefly together before dealing with each separately. Outbreaks of either disease can produce virtually identical results in a herd, and the two diseases can often be identified separately only by laboratory procedures. Both produce the typical picture of temporary infertility in susceptible cows and heifers without apparent abnormality in the bull. In both diseases immunity develops in infected females and after a time (usually from three to six months after infection) breeding returns almost to normal, and the disease assumes a chronic course in the herd. At this stage, occasional abortions (these are never very frequent) may occur and heifers and newly introduced cows usually show temporary infertility for a few months before conceiving. In both diseases, infection in the bull is permanent, and this leads to periodical breakdowns to the acute stage of the disease as resistance wanes in the females. Both diseases are purely venereal, i.e. infection passes only at coitus, but both can be transmitted by the semen of infected bulls used in artificial insemination. This in fact has been the method by which widespread dissemination of the disease has occurred in many countries, and it might be mentioned here that Kenya farmers are most fortunate in that the rigorous control measures exercised at the Central Artificial

Insemination Station at Kabete have been such that neither disease has ever gained access to the stud.

Despite the apparent similarities in the clinical results of trichomoniasis and vibriosis, when it comes to the question of control measures, there are most important differences between them, and for this reason it is essential that a differential diagnosis should be made in every case where either disease is suspected.

It should be added that the two diseases quite frequently exist together in the same herd.

Trichomoniasis

There is no doubt that this disease is widespread in the European farming areas of Kenya. Trichomoniasis takes its name from that of the causative organism, *Trichomonas foetus*. This is a pear-shaped protozoal organism, of a much greater size than most bacteria, which swims actively and with a characteristic type of motion in natural fluids. Because of its size, shape and motility, it is easily recognized under the microscope, and any farmer who is accustomed to the use of this instrument, and who has cause to suspect the presence of trichomoniasis in his herd, may be able to help himself considerably by learning to identify the parasite for himself. Cultures of trichomonads are kept at Kabete and Naivasha, and the staff of these laboratories will always be pleased to demonstrate the simple method involved.

The Disease in the Individual Animal

Trichomoniasis is a highly infectious disease affecting the reproductive organs of both male and female cattle. Infection is by the venereal route, and can pass from an infected cow to a clean bull at natural service and vice versa. The infected bull is, of course, the means of spreading infection widely and rapidly through the herd.

In the bull the infecting organism is found only on the surface of the mucus membrane covering the penis and lining the sheath, or prepuce. It does not invade the tissues of the region but maintains an existence in which the host animal suffers no damage of any kind to its tissues and shows no clinical symptoms whatever. A bull, once infected, remains a permanent carrier of the disease unless treated by one of the methods described later. His ability to serve and to get calves (apart from the temporary infertility his services cause in susceptible females) remains unimpaired throughout. It should be appreciated that although the bull has been described as "infected", there is no true infection in the sense that the animal's tissues are invaded by *Trichomonas*. Consequently, the disease-resisting mechanisms of his body are never called into play; he develops no immunity to the disease, and so fails to rid himself of the organisms.

In the female the position is entirely different. The organisms do in this case provoke extensive tissue reactions, with the result that an effective immunity develops rapidly in the infected female. This enables her in the great majority of cases to make a spontaneous recovery from the disease, and this recovery is invariably what we describe as "sterile". This means that the infecting organisms disappear entirely and the animal is no longer infective at natural service to a clean bull.

Bearing in mind this important factor, we may now proceed to consider the different courses which the disease may take in the newly infected cow or heifer. These vary considerably, depending on the delicate balance between the intensity of infection and the speed and effectiveness of the development of specific resistance to the disease.

The early stages of trichomoniasis in the female are the same in all cases. Infection is almost invariably acquired at the first infective service, and organisms in large numbers can consistently be found in the vagina from 7 to 14 days later. From this site of initial colonization, the trichomonads usually migrate very quickly to the uterus, where some degree of endometritis (inflammation of the uterus) follows. This is often, though not invariably, sufficiently intense to prevent conception or to terminate an existing pregnancy. The further progress of the disease depends upon whether or not the animal has become pregnant to the first infective service. Many animals do so, but it will be simpler to consider first the course of the disease in the animal which fails to conceive to this service.

In this animal endometritis persists for a period of up to about three months. During this time there is no interference with the oestrus cycle so that the animal comes into heat at regular intervals, but she cannot become pregnant as long as inflammation persists in the uterus. During this time the organisms are present in the uterus, from which they are

discharged afresh into the vagina at each oestral period, rendering the animal infective to any clean bull which may serve her. The specific resistance to the disease which, as already mentioned, develops rapidly in the infected female, enables recovery to take place, and by the time that four complete oestrus cycles have occurred following infection, all animals in this category have made a spontaneous recovery from the endometritis, and have eliminated the trichomonads completely from their systems. They are no longer infective, their reproductive organs are perfectly healthy, and so far as trichomoniasis is concerned there is no obstacle to their conceiving at the next service. Further, because they are now immune to the disease they will not contract it if served by an infected bull; an infective service is just as likely, in fact, to prove fertile as an uninfected one.

Let us summarize the course of events in this class of animal. When uncomplicated by pregnancy, the disease causes a temporary sterility affecting, most commonly, four or five successive services. The female shows regular returns to oestrus during the period, and she makes a spontaneous, sterile recovery within 12 weeks of initial infection.

As stated above, many cows and heifers become pregnant to the first infective service. In these animals the course of the disease is governed by the length of time during which pregnancy persists and by the manner in which it is terminated. Pregnancy may be terminated—

(*a*) by early death of the embryo,

(*b*) by abortion at any subsequent stage of pregnancy,

(*c*) by death of the foetus *in utero*, with the development of pyometra (pus in the uterus),

(*d*) by normal parturition.

By far the commonest is early foetal death, in which case there is seldom any obvious evidence of an embryo having been present and it is assumed that conception did not occur. The animal returns to heat after anything from the normal 21 days up to several months, and then resumes the normal oestral cycle. If she returns in the early stages (about 30 days after the infected service is common) then she remains infected and infertile until immunity develops and she recovers from the disease at about the twelfth week. Abortions may occur at any stage of pregnancy, but abortions are not an outsanding feature of trichomoniasis and often they are completely absent.

Pyometra also is relatively uncommon. This condition really represents an abortion in which the foetus is not expelled but remains in the uterus. It is of interest in that it is the only condition resulting from trichomoniasis in the female which can produce permanent sterility, and also it is the only one requiring treatment (this should be on conventional lines, directed towards evacuation of the uterus).

In the case of both abortion and pyometra, trichomonads are present in the uterus in large numbers until the time of abortion or evacuation of the uterus, but the animal has invariably acquired a high degree of immunity, so that by the time of the next oestrus period, she has completely rid herself of infection.

In the case of the animal which calves down normally, the supposition is that she received initially only a very mild dose of infection, or perhaps none at all. In any case, she will be free of infection by the first oestrus period following parturition.

The Disease in the Herd

The course of trichomoniasis in an infected herd can usually be divided into three phases.

The first, or acute, stage occurs when infection is first introduced into a susceptible herd. The most striking feature is the number of infertile services. Returns to the bull at irregular periods after service are noticed. Often, practically all females serviced by the infected bull show this temporary sterility.

This phase gradually merges into the second or sub-acute stage. The number of infertile services becomes lower and an increasing proportion of animals settle in-calf. The sub-acute phase extends usually for about six months, with fertility gradually improving as resistance is acquired. During this time some animals which appeared to have conceived during the early stages may return to service, either with or without observed signs of an aborted foetus. Later, occasional abortions may be observed, but the incidence of these is invariably low. At this time, too, mucopurulent vaginal discharges may be observed, especially in pregnant animals and in any with pyometra. Such discharges are only rarely seen in the early stages of the disease, but are fairly common later.

When resistance to infection has been acquired by all females, then if no control measures are applied, the disease assumes its chronic, or latent, phase. Breeding becomes almost normal except perhaps for occasional irregularities in oestrus cycles and sporadic abortions. At the same time, previously unexposed animals, such as heifers or brought-in cows, become infected and suffer temporary infertility until they acquire resistance. The infection may remain latent for long periods, but commonly intervals of acute disease occur as a result of a breakdown in resistance.

Diagnosis of the Disease

Although the presence of trichomoniasis in a herd may be suspected from the symptoms, it is not possible to diagnose the disease on symptoms alone, as these are almost identical with those seen in other breeding diseases, particularly vibriosis. To reach a certain diagnosis it is necessary either to recover *Trichomonas foetus* from infected cattle, or else to show positive results in vaginal mucus agglutination tests.

The parasites can be observed microscopically, and also recovered by cultural methods, using a variety of material from infected animals. The materials used are:—

(*a*) Stomach contents and other tissues from aborted foetus.

(*b*) Allantoic and amniotic fluids from an early abortion.

(*c*) Vaginal mucus taken from a susceptible animal during the second week after infection.

(*d*) Vaginal mucus taken immediately before the onset of oestrus, from three-nine weeks after infection. This is often a clear, watery fluid containing flakes of pus.

(*e*) Mucopurulent material discharged by some pregnant cows and those with pyometra.

(*f*) Sheath washings from the bull.

A further diagnostic method now available is mucus agglutination testing. This is a laboratory procedure depending upon the appearance of antibodies in the vaginal mucus of infected female cattle. The test is extremely useful in diagnosing infection in a herd, but has only limited value in diagnosis in the individual animal.

Sometimes, in the case of valuable bulls, it is worth while, for the sake of a reliable diagnosis, to make use of a test mating procedure. One or more virgin heifers are served by the suspect bull, using either natural service, or, even better, artificial insemination with the addition of sheath washings to the semen. Attempts are then made to demonstrate infection in the heifers, and as diagnosis in the female is simple and more reliable than in the male, a much more dependable diagnosis can be made than if only the bull's sheath washings are examined.

Eradication of the Disease from the Herd

The principles on which control measures are based may be enumerated:—

(*a*) Transmission of infection is purely venereal.

(*b*) The infected bull remains permanently a carrier of the disease unless treated.

(*c*) The infected female rapidly acquires immunity and makes a spontaneous sterile recovery.

There are four possible ways in which the disease may be eradicated.

The simplest method of dealing with it, and the one least liable to failure from accident or negligence, is to dispose of all bulls and to adopt artificial insemination, using semen from known healthy bulls, in place of natural breeding. The herd may be regarded as free from disease as soon as all females have undergone normal pregnancy or recovered from abortion or pyometra.

The other three methods depend upon division of the herd into two units, clean and infected, and success depends on the certainty of the initial separation. The clean group must be beyond all question uninfected, and if any doubt at all exists regarding any individual animal it must go into the infected herd. The decision on each animal must depend only on breeding history—no laboratory test is of any assistance here. Often it will be found that the only animals beyond suspicion are maiden heifers and unused bulls. It should be added that, because of the venereal character of the disease, the two groups need not be separated physically, but are only regarded as separate units in respect of the bulls to which they are bred. A high standard of supervision and management is absolutely essential if any one of the segregation methods is to be used, because a single mistake can result in the appearance of the disease in the clean herd. Constant care and vigilance are

necessary, and the stockowner must understand clearly the nature of the disease and the way in which it spreads.

The three segregation methods are set out below. In all three methods, after division of the herd into "clean" and "infected" groups, natural breeding may be practised from the start in the clean groups, and the remarks under (*a*), (*b*) and (*c*) refer only to the infected group.

(*a*) Infected bulls are removed. All breeding ceases for three months, during which time non-pregnant animals recover. Pregnant animals which either abort or calve normally are not bred until three months have elapsed and the second heat has appeared following abortion or parturition. Animals with pyometra are treated in the same way as aborting animals following evacuation of the uterine contents. Breeding may be by natural service from clean bulls while the scheme is in operation. Infection can be eradicated in from one to two years.

(*b*) An improvement on (*a*) is to remove infected bulls and introduce artificial insemination with healthy bull semen into the infected herd. As there is no danger of infection passing back to the bull, breeding may commence immediately and consequently there is a saving of valuable time because many lightly infected or non-infected females will conceive during the first three months, and all should be in-calf by the end of that period. As before, when all animals have calved, aborted or recovered from pyometra, and a further three months have passed and the second oestrus period has appeared, the group may be considered free of infection and natural breeding may be resumed. Under this plan also eradication takes from one to two years.

(*c*) The third method is aimed at control rather than eradication. The infected group, both bulls and females are simply kept separate for breeding, which is by natural service. The chronic disease remains permanently in the infected herd but fertility becomes reasonably satisfactory. Relapses are almost certain to occur. The great drawback to this scheme is obvious, the permanently infected group representing a constant threat to the healthy group. Eradication can only come about if the groups are, in fact, maintained entirely separate until the infected herd has been eliminated in the course of time.

Treatment in the Bull

When particularly valuable bulls are found to be infected, there are several types of treatment which can be employed. None can be guaranteed to be effective, although probably at least 90 per cent of bulls are curable if persevered with. Any type of treatment must be followed by careful diagnostic tests (test mating is preferable) to determine whether or not treatment has been effective.

Local treatment consists of the application of antiseptics of various kinds to the penis, terminal urethra and preputial mucous membrane. Epidural or appropriate nerve block anaesthesia is necessary to bring about relaxation of the penis.

The most effective antiseptics reported on are euflavine used as a one per cent solution on swabs and as a 0.5 per cent ointment, hydrogen peroxide in three per cent solution used as a pressure spray or injected into the preputial cavity, various detergents such as "Cetavlon" in 0.1 per cent solution, and organic silver and mercury compounds (collargol, penotrane). In all methods described, great pains are taken to ensure deep penetration of the antiseptic into all the folds and crevices of the mucous membrane in which the trichomonads live.

Mention should also be made of systemic treatment with sodium iodide, used intravenously at the rate of 30–50 gm. per 1,000 lb. bodyweight, repeated three to five times at 48-hour intervals. Although this treatment is not very effective used alone, it is considered a useful adjunct to local antiseptic treatment.

VIBRIOSIS

There is no doubt that genital vibriosis is widespread in the European farming areas of Kenya. The disease takes its name from that of the causative organism *Vibrio fetus.*

In a great many respects, the disease caused by *Vibrio fetus* is very similar to that due to *Trichomonas foetus,** but in one most important respect they differ. Trichomoniasis

*The difference in spelling is due to the fact that *V. fetus* was first named in an American journal, and *T. foetus* in an English journal.

can fairly easily be eradicated from a herd; vibriosis, although it may be brought under control and cease to be a breeding problem, is much more difficult to eradicate completely from an infected herd.

Transmission of Infection

All mature cattle, both male and female, are highly susceptible to vibriosis. It is believed, indeed, that when an infected bull serves a healthy cow, or a healthy bull serves an infected cow, the probability of infection passing is very nearly 100 per cent.

Infection occurs almost invariably by the venereal route, and this is the only important method of spread under practical farming conditions. Both bulls and cows therefore spread the disease, and the bull is often responsible for spreading it rapidly through a susceptible herd. In sharp contrast with trichomoniasis, however, one particular type of cow plays an important part in spreading vibriosis. This is the animal which has recovered from the disease in the sense that she has recovered her fertility but who still harbours *Vibrio fetus* in her reproductive system. She is still infective to healthy bulls, although showing no sign of disease herself. It is the existence of such healthy female carriers of vibriosis that is directly responsible for the difficulty in eradicating the disease.

The Disease in the Individual Animal

In the infected bull the causative organism is found in the sheath or prepuce, and never at any other site. Probably because of the lack of any tissue invasion, the bull never acquires any immunity and consequently remains infected permanently. He shows no symptoms of infection whatever, and he may be reasonably fertile when used on resistant cows. His semen contains *vibrio* organisms and is infective both at natural service and by artificial insemination.

In the infected female, the organism occurs in the uterus and vagina, in both of which organs it is capable of setting up inflammation (endometritis and vaginitis). These inflammatory reactions are of themselves sufficient to prevent conception so long as they last, but the full story of how *Vibrio fetus* affects the reproductive system is not yet known. We must simply accept that it causes temporary sterility lasting usually up to some three or four months, with occasional abortions at any stage of pregnancy.

Infection in the female stimulates specific resistance to the disease, so that vibriosis is to some extent self-limiting in most cases after a period of three to six months. It is not yet known how long this immunity lasts, nor whether immunity to one particular strain of the organism is effective against other strains, nor what is the relation between immunity and the carrier state already mentioned.

The symptoms observed in cows and heifers following infection are rather variable. Vaginal examination often shows vaginitis with an increased secretion of mucus. The mucus is usually clear or occasionally slightly cloudy, but it is seldom really dirty. The inflammation of the vagina is usually most intense in the region of the cervix, and it extends through the cervix and into the uterus itself.

During the early stage of the disease, many of the infected animals apparently fail to conceive, returning to service repeatedly, and often at irregular and prolonged intervals. It is probable that conception actually occurs in many cases but that it is followed by early foetal death with reabsorption or expulsion of the embryo. The exact position, however, is not known with certainty. If breeding is continued, the majority of infected animals become pregnant after three or four months, but some animals persistently fail to conceive. Later, a proportion of pregnant animals may abort. Pyometra, such as is described in trichomoniasis, is not a common feature of vibriosis.

The development of specific resistance which occurs some three months after infection is in the majority of cases sufficient to bring about both clinical recovery from the infertility and also complete disappearance of infection from the animal. In a proportion of cases, however, even though fertility may be restored, infection does not disappear, and the animal becomes a symptomless carrier. It is not quite certain how long the carrier state can persist. Infection has been demonstrated after the first normal parturition following infection, so it is not safe to assume that an animal is clean following a full-term calving. It is believed, however, that by the time she has undergone two normal gestations, she can safely be assumed to be clean.

The Disease in the Herd

The characteristic features of an outbreak of vibriosis in a susceptible herd are the abnormally high number of infertile services,

and the irregular and often protracted oestrus cycles. In the early stages following infection, few animals, perhaps as few as one in every three, settle to the first service. The acute stage commonly lasts for from three to six months, after which, with the development of specific resistance, the disease gradually assumes the chronic form. When this stage is reached, fertility is usually fairly satisfactory throughout the resistant stock, but temporary infertility still occurs in heifers or other females newly introduced to the herd. Occasional abortions may occur at any stage of gestation but most commonly about the fifth or sixth month. The incidence of abortion is usually low but varies between outbreaks, some showing a fairly high abortion rate and others none at all.

Although this may be accepted as the typical picture of the disease in a herd, departures from it are common, particularly in the case of the chronic disease. In some herds this causes a great deal more breeding trouble, by way of repeat breeders, complete sterility, and frequent abortions, than has been indicated above. In other herds, the disease seems to adopt a passive role, and trouble is confined, and then briefly, to newly introduced heifers. Often, too, the amount of trouble caused by the chronic disease seems to vary, irregularly, from year to year.

Diagnosis of the Disease

Although the symptoms observed in a herd may suggest the presence of vibriosis, diagnosis can never be based on symptoms alone, because these strongly resemble those seen in trichomoniasis and may, in fact, be confused with those of other breeding diseases. Accurate diagnosis can only be made by laboratory methods in which either the causative organism is demonstrated in material from infected cattle or specific antibodies are shown by serological tests.

(*a*) *Bacteriological methods.*—These can be applied to aborted foetuses, to mucus or mucopurulent material from the vagina and in the case of the bull, to semen or, better, sheath washings. In order to demonstrate the organism in the laboratory, it is usually necessary to recover it in culture. Vibrio is a very delicately growing organism and is easily overgrown by contaminants when these are present. It is essential, therefore, that material submitted to the laboratory for vibrio examination should be as fresh as possible, certainly not more than 24 hours old, otherwise there is little chance of isolating the organism. Samples such as vaginal mucus or sheath washings must be taken with strict precautions to minimize contamination.

The aborted foetus is very often the most favourable material to submit for diagnosis of vibriosis. If the abortion was, in fact, due to vibriosis, and the foetus reaches the laboratory quickly enough, the organisms can almost invariably be recovered quite easily. No other method offers the same chance of a rapid and certain diagnosis, and farmers with infertility problems should always regard the sending in of aborted foetuses as a matter of the utmost importance and urgency.

(*b*) *Serological methods.*—These depend upon the appearance in the vaginal mucus from infected females of specific antibodies which can be demonstrated in an agglutination test. This type of test is extremely useful in proving the presence or absence of infection in a herd, but it has little practical value as a test applicable to individual animals.

Diagnosis in the Bull

Diagnosis in the bull is frequently of prime importance, not only because he is often the only animal in an outbreak who can be known with certainty to be infected and carrying the organism, but also because of the necessity to prove freedom from infection, for example, before allowing a bull to enter a clean herd or an artificial insemination stud. Unfortunately, direct diagnosis in the bull is much more difficult and less reliable than in the female. Only bacteriological methods are available, and the material used for the purpose (semen and preputial washings) are invariably contaminated, rendering diagnosis difficult and frequently impossible. On the other hand, cultural examination of vaginal mucus from an infected female, particularly from 7 to 30 days after infection, is a very reliable procedure. Accordingly, test mating methods have been devised in which the bull serves or inseminates a virgin heifer and a series of appropriate tests are applied to determine whether or not any infection has passed to the heifer. Test mating is a good method of diagnosis in the bull but is possible only with the co-operation of a laboratory.

The limitations of these diagnostic methods are of some importance. In the bull it is possible, by test mating, to reach a firm diagnosis, whether positive or negative, in a

reasonable time. In the female, bacteriological examination of mucus is a reliable method in the early stages of the disease, but after a month or two the demonstration of organisms is possible only fortuitously. Nor does the mucus agglutination test help us to diagnose the presence or absence of infection in the individual female, because a positive result usually indicates a recovered animal rather than an infected one, and a negative result is not conclusive. Thus it is extremely difficult to prove the presence of the disease in a chronically infected female and it is virtually impossible to prove its absence.

Control and Eradication of the Disease on the Farm

Control measures must take into account two important factors:—

(*a*) Infection in the bull is permanent, unless successfully treated.

(*b*) Transmission of the disease is purely venereal under normal farming conditions.

Basing our measures on these two facts, it is easy to devise a scheme which will bring about control of vibriosis in the sense that normal or nearly normal fertility can be restored to the herd and further spread of the disease within the herd can be prevented.

Complete eradication of the disease, however, is a more difficult problem, and here the important factor is the carrier female liable to survive any acute outbreak. Because the carrier cannot be identified, and cannot be prevented from appearing by any form of treatment at present available, it must be assumed that carriers exist in any group of exposed animals until such time as every animal in the group has undergone two normal pregnancies following the last possibility of infection.

Control of vibriosis may be considered under two headings: (*a*) control by artificial insemination, and (*b*) control by breeding segregation. In practice various combinations of the two methods are often adopted to meet individual circumstances.

Control by artificial insemination

The most effective method of control is undoubtedly to dispose of all bulls and to introduce artificial insemination with semen of known healthy bulls. This has the immediate effect of halting the further spread of infection in the herd, so that healthy females remain uninfected and become pregnant with the least possible delay. Further, there are distinct indications that healthy semen has a beneficial effect on the fertility of infected animals, and such of these as remain carriers after the acute disease has subsided are prevented from transmitting infection by the absence of natural service.

Under artificial insemination it is usual for the impaired herd fertility to improve considerably within the space of a few months, reaching a normal or nearly normal level within a year. At this stage, however, despite the virtual disappearance of clinical infertility, the existence of carriers precludes any early attempt to resume natural breeding, and artificial insemination must be continued until all animals are know to be safe, i.e. until every animal has produced two normal calves. If after this time a return to natural breeding is attempted it is important that the most precise records should be kept of dates of service and returns to service. Records of this kind provide the earliest possible evidence of recrudescence of infection.

A note of warning must be introduced regarding the technique of artificial insemination in an infected herd. Some farmers find insemination difficult without the aid of a vaginal speculum, and it is vitally important that when this instrument is used it should be sterilized *after every individual insemination.* Adequate sterilization requires the following procedure:—

(*a*) Thorough washing with soap or detergent and water to remove all traces of adherent mucus.

(*b*) Followed by complete immersion in vigorously boiling water for at least five minutes.

Immersion in water containing antiseptic is *not* effective. It cannot be too strongly emphasized that a dirty speculum can spread disease throughout a herd quite as effectively as an infected bull. The technique of insemination *per rectum* is greatly to be preferred to that involving the use of the speculum.

Control by Breeding Segregation

Control of vibriosis can also be brought about by a policy of controlled breeding with or without the use of artificial insemination. When this method is used the herd must first be divided for breeding purposes into two

groups—clean and infected. Physical separation of the two groups is not necessary; all that is needed is that they should be treated as separate units for breeding purposes. The decision as to which group each animal should enter must be based upon breeding history alone, and it is most important that the clean herd should be absolutely beyond suspicion. If there is the slightest doubt about any particular animal it must be included in the infected group. Often the only animals which can at first be placed in the clean group are unbred heifers and young bulls not yet brought into use. To the clean group will be added from time to time young heifers representing the natural increase from both clean and infected groups, so that the clean herd constantly increases while the infected one diminishes as animals die or are disposed of. Once the division into groups is made, the separation between them for breeding purposes must be rigidly maintained so long as the disease remains on the farm. The stockowner and attendants must understand fully the principles on which control is based, and must exercise constant vigilance to prevent accidental breeding between the groups.

In the clean portion of the herd, breeding may be either by natural service or by artificial insemination. In the dirty herd several courses are open:

(*a*) Natural service, using the existing infected bulls. As soon as the acute phase of the disease is over, with resistance appearing as a result of infection, fertility reaches a fairly satisfactory level, although occasional animals may become sterile and occasional abortions occur. There may be flare-ups of the disease due to reinfection of females as their immunity wanes. Infection may be expected to persist until every animal in the group has been eliminated in course of time.

(*b*) Removal of infected bulls and replacement of natural breeding by artificial insemination. This is the course to be recommended. It prevents further spread of infection to those females as yet uninfected, thereby avoiding temporary sterility in these animals, and it eliminates the danger of accidental breeding between the clean and dirty groups. It offers also the great advantage that the suspect groups may be considered clean, and breeding segregation discontinued, as soon as every animal in the group has undergone two normal pregnancies.

(*c*) In some cases the best course may be to treat affected bulls and after they are proved cured to use them by artificial insemination. There is, of course, no point in treating bulls for future use with suspect females unless artificial insemination is used because cured bulls are fully susceptible to reinfection.

Treatment

Treatment of vibriosis in the bull is feasible and justified when subsequent re-exposure to infection can be avoided. Many forms of treatment have been used with varying degrees of success, and finality has by no means yet been attained. However, treatment by preputial irrigation for one hour with a suspension of penicillin and streptomycin in an oily vehicle repeated on three successive days, seems to cure the great majority of cases. Treatment should always be followed by test mating with a maiden heifer in order to prove that it has been successful. The procedure is not to be undertaken lightly; occasional cases have been reported of infection reappearing many months after apparently successful treatment.

Treatment is possible also in the female, but there is even less certainty about the form it should take because of the much greater difficulty of assessing results in the cow or heifer than in the bull. The recommended drugs are penicillin, streptomycin and aureomycin, and these have been used both locally, by intra-uterine irrigation, and also systemically by injection. It is not possible at present to accept any form of treatment as 100 per cent effective, but there can be little doubt that the course of an acute outbreak of vibriosis in a herd can be reduced in intensity by the appropriate use of antibiotic treatment in the females.

CONCLUSIONS

Descriptions have now been given of three diseases which together are responsible for a large part of the breeding troubles so common throughout the European farming areas of Kenya.

It will have been observed what a large part is played in control of these diseases by artificial insemination. It is indeed in many cases the only measure which offers to the farmer any hope whatever of ridding the herd of disease.

Besides herds in which one or other disease has been diagnosed, there are undoubtedly present in the country a number of herds in which low fertility exists without any distinct indication of the presence of specific disease. Many such herds would benefit from the introduction of artificial insemination.

Further, artificial insemination can be recommended unreservedly to the owner of a herd unaffected by breeding disease. It is virtually impossible under conditions obtained in Kenya to prevent any possible chance of infection entering a clean herd, but artificial insemination can offer a certain guarantee that if infection does enter, it will remain localized and will not spread throughout the herd.

Failing the adoption of artificial insemination, the best means of safeguarding a healthy herd is to restrict additions to the herd to unbred bulls and heifers. Any bull which has been used for natural service and any female which has been served naturally should be excluded unless they are derived from a herd which is known with certainty to be free of infectious breeding disease.

DIFFERENTIAL FEATURES OF "EPIVAG", TRICHOMONIASIS AND VIBRIOSIS

	"EPIVAG"	TRICHOMONIASIS	VIBRIOSIS
Causal organism ..	Unknown, probably a virus.	Protozoan—*Trichomonas foetus.*	Bacterium—*Vibrio fetus.*
Transmission	Venereal. Possibly also insect borne.	Venereal.	Venereal is the only route of practical importance to the farmer.
Incubation period—			
Male	From 2 months to several years.	Immediate infection.	Immediate infection.
Female	Average 4–5 days.	One week.	Two weeks.
Symptoms—			
Male	Enlargement and hardening of epididymis. Poor quality semen.	None.	None.
Female	Temporary infertility. Vaginitis with typical discharge.	Temporary infertility with returns to service at regular or irregular intervals.	Temporary infertility with returns to service at regular or irregular intervals.
Pathological changes—			
Male	Epididymitis and occlusion of the ductus deferens.	None.	None.
Female	Vaginitis and endometritis. Sometimes forward spread of infection resulting in permanent sterility.	Vaginitis and endometritis.	Vaginitis and endometritis.
Duration of infection—			
Male	Permanent.	Permanent.	Permanent.
Female	Clinical disease lasts up to six months.	Maximum of 3 months in non-pregnant animals. Until oestrus following calving or abortion in others.	Most animals recover clinically within 3–4 months.
Immunity in female ..	Unknown. Native cattle resistant. Carriers exist.	Effective immunity develops lasting 2 or three years. Carriers do not exist.	Effective immunity develops. Duration unknown. Carriers exist.
Diagnosis	Based on clinical findings only.	Aborted foetus. Vaginal mucus. Sheath washings. Test mating. Mucus agglutination.	Aborted foetus. Vaginal mucus. Sheath washings Test mating. Mucus agglutination.
Treatment—			
Male	None.	Local application of antiseptics.	Local application of antibiotics very effective.
Female	None.	Not necessary or advisable.	Antibiotic treatment reduces severity of acute phase of disease.
Control—	Elimination of infected bulls. A.I. Introduction of native bull. Segregation of little practical value.	Elimination or treatment of infected bulls. 3 months sexual rest period with resumption of natural breeding. A.I.	Elimination or treatment of infected bulls. Segregation. A.I.
Eradication—	Continued use of A.I. until suspect animals are eliminated from herd.	Spontaneous recovery in female renders eradication fairly easy.	Presence of carriers among recovered females hinders eradication. Eradication possible by continued use of A.I. until all suspect animals have undergone two normal gestations.

NOTES ON ANIMAL DISEASES
XVII—MISCELLANEOUS DISEASES CAUSED BY BACTERIA
PART II*—JOHNE'S DISEASE

Compiled by the Department of Veterinary Services, Kenya

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Johne's disease is an insidious disease affecting cattle, sheep and goats; it is characterized by an extremely long incubation period and it causes scouring, wasting and eventually death in affected animals. It is as a disease of cattle that Johne's disease is of growing importance in Kenya. It has never been diagnosed here in sheep or goats, and if it exists in these animals it probably does so only on a minor scale. Sporadic cases of the bovine disease have been known in Kenya for many years, and it is now recognized that infection is widespread throughout the Colony and is the cause of much economic loss, particularly in certain high rainfall areas. Because of its insidious nature the disease may not become apparent for many months, sometimes even years, after infection gains entrance to a herd; by the time the first two or three clinical cases have appeared, a large proportion of the herd may be infected.

The Cause of the Disease

Johne's disease is caused by a micro-organism known as *Mycobacterium johnei*. This belongs to the same group of bacteria as the tubercle bacillus, with which it shares certain properties, notably a high degree of resistance to drugs and disinfectants of all kinds, including such natural agencies as heat, light and drying. This high resistance greatly increases the difficulty of eradicating the disease. In Britain, the organism can survive for periods of up to 12 months in soil, dung and water, and there is little doubt that conditions for its survival are at least as favourable in many of the cooler and wetter parts of Kenya.

M. johnei grows very slowly in artificial culture, and often several months' incubation are necessary before growth becomes apparent. Identification of the organism with the certainty demanded in scientific experiments is also exceedingly slow; it depends on reproducing the typical disease in susceptible animals. These factors, together with the long incubation period of the disease, render experimental work extremely slow, and experiments may take several years to achieve valid results.

Transmission of the Disease

Johne's disease is essentially a chronic inflammation of the bowel. The organisms, often in enormous numbers, multiply in the tissue cells of the lining of the bowel, and in the clinical case of the disease these parasitized cells become detached and pass out in the fluid faeces. Thus both pasture and water supplies become heavily contaminated with the organisms and infective to other animals who may ingest them with food or water.

In the predominantly hot, dry areas of Kenya there is no doubt that the sterilizing effect of intense sunlight is sufficient to kill out infection relatively quickly. In other, cooler and wetter districts, ground infection is probably an important factor in transmission of the disease, and it is certainly true that the highest incidence of infection is found in such areas.

Water-borne infection is believed to be particularly important in Kenya. Watering troughs, and more especially, unfenced dams, can easily become grossly contaminated with virulent infection capable of persisting for many months. It is difficult, indeed, to imagine any better vehicle of infection than an open dam, in which vast numbers of organisms are collected and preserved under the most ideal conditions for their survival.

Infection of grazing animals from contaminated food or water is not, however, the most important factor in the spread of Johne's disease, because we believe that the majority of animals which acquire infection do so as young calves. Calves are highly susceptible to the disease at birth and this susceptibility decreases rapidly up to about six months of age, after which it is difficult to produce experimental infection even with doses many times greater than the calf is likely to encounter naturally. Infection can also pass *in utero* from an infected dam to her unborn calf, and this seems to occur frequently when

* Part I of this series was published in this *Journal*, Vol. 8, 1943, p. 184.

the dam is in an advanced stage of the disease. Thus many calves undoubtedly contract Johne's disease either before birth or else during the first few weeks of life. The danger to the suckling calf is twofold; more important is the danger of infection from faecal contamination of the udder region in the mother, but also, since the organisms of Johne's disease have been isolated from the udders of infected cows, the milk itself may be infective despite effective hygiene in preventing faecal contamination.

The Course of the Disease in the Infected Animal

The incubation period of Johne's disease is always very lengthy. Following natural infection, it is rarely less than 12 months before symptoms develop, and it is often several years, sometimes many years. This, of course, constitutes another major obstacle to control of the disease. The symptoms in an established case are easily recognizable. There is a profuse diarrhoea, often intermittent at first but later becoming continuous. The faeces are thin and watery, sometimes, but not always, containing bubbles; they are always normal in colour and never contain blood. Associated with the scouring is a progressive loss in condition which leads rapidly to complete emaciation. To casual observation the wasting usually appears more pronounced in the region of the hind quarters than in the fore quarters. Together with these symptoms and sometimes preceding them there may be a fading in the colour of the coat, especially noticeable in Channel Island cattle. Many farmers with experience of Johne's disease believe this to be a valuable warning sign of impending breakdown to the clinical disease. Once scouring is established, the disease is invariably progressive and leads to death; a scouring animal with Johne's disease should be slaughtered immediately—it will always get worse, never better, and it is a constant source of infection to other animals.

We have seen that an animal which acquires infection may become a clinical case months or years later, but many such animals, including some infected during the early period of high calfhood susceptibility, never develop the clinical disease at all. Some may suffer a mild sub-clinical attack with or without scouring and then recover completely. Others become carriers of the disease and may pass infective faeces, either continuously or intermittently, over long periods of time. Carriers of this kind are very difficult to identify with certainty and they constitute a third major difficulty in control of Johne's disease.

The clinical disease occurs most commonly in animals between three and five years of age, and it often appears after calving or some other strain on the constitutional resistance of the animal. It is also believed that hereditary susceptibility may exist, so that some blood lines of cattle may be more liable to Johne's disease than others. Although it is well known that the disease is common in Channel Island cattle, there is no scientific evidence that these breeds, or, in fact, any other particular breed, are especially susceptible to infection. It seems certain, however, that no breed is immune. Regarding indigenous African cattle, we have, as yet, very little knowledge of the disease in this type of stock. beyond that it has been known to occur.

Not the least of the problem posed by this disease is the reason why it should produce widely differing disease pictures on different farms. In some outbreaks, almost every infected animal rapidly becomes a clinical case and severe losses occur. In others, despite the presence of infection in a large number of animals, breakdown to the clinical disease is seldom seen. Thus a heavy incidence of subclinical infection may well go unsuspected for years, the only clue to its presence being that animals sold to other farmers may break down when placed in a new environment. This suggests that a "trigger factor" of some kind exists, and determines whether the disease remains quiescent in an animal or herd, or whether it progresses to become a clinical problem. Of the nature of this "trigger factor" we are completely ignorant. Various mineral or nutritional deficiencies may be responsible, particularly lack of calcium and phosphorus in the soil and herbage, but such suggestions are unsupported by experimental evidence.

The true incidence of the disease throughout Kenya is not yet known, but cases have been reported from all parts of the Colony. A recent survey has shown that infection rates up to 10 or 15 per cent are found on the worst infected farms, but such rates are exceptional and occur only in association with high rainfall or with unfenced dam water supplies. When these factors are absent the incidence seldom exceeds 2 or 3 per cent.

Diagnosis of the Disease

At present there are four diagnostic methods of varying reliability.

Microscopic Examination of Faeces

It is sometimes possible to demonstrate the presence of Johne's organisms in the dung of infected animals by examining an appropriately stained film under the miscroscope. Only fluid samples of faeces from scouring animals are useful for this purpose as dung of normal consistency never contains the organisms in demonstrable numbers. The method is of limited value because even in the advanced clinical cases organisms may be excreted only intermittently, so that failure to find organisms does not prove freedom from infection. However, it is well worth trying, especially when it can be repeated at intervals or when samples can be submitted from a number of animals at one time, because if organisms are found an immediate and certain diagnosis is possible. Probably less than half of all animals in the scouring stage of the disease are detectable by this means, even after repeated sampling.

Post-mortem Examination

The post-mortem lesions are quite characteristic and consist of thickening and corrugation of affected parts of the bowel wall. They are found most frequently in the terminal portion of the small intestine, in the caecum in the vicinity of the ileo-caecal valve, and in the first portion of the large intestine. The lesions are proliferative only, i.e. they are chronic in type, consisting of swelling and thickening of the mucous membrane of the bowel; acute inflammation and ulceration do not occur. Diagnosis can be confirmed by laboratory examination of pieces of bowel and associated mesenteric lymph gland. It should be added that it is frequently difficult to correlate the post-mortem picture with the clinical history. Lesions are often inconspicuous even in advanced clinical cases and conversely severe lesions may be found in animals which never showed symptoms in life.

Blood Testing

A blood complement fixation test is available which is probably the most accurate method of diagnosis in the living animal. This test has certain limitations which detract from its value when used as the basis of control measures. It has considerable value as a screening test applicable to an animal entering a clean herd.

Allergic Test (Johnin Test)

Although a number of antigenic substances have been used in attempts to devise an allergic skin test of the same type as the tuberculin test, none has been found satisfactory for routine diagnostic use.

CONTROL MEASURES

The most important obstacles to the control of Johne's disease have already been mentioned. They are:—

(1) The high resistance of the causal organism.
(2) The lengthy incubation period.
(3) The existence of carriers, identifiable only with great difficulty.

Because of these adverse factors, effective control can be achieved only as a result of measures applied consistently over a period of at least several years.

Hygiene and Management

Hygienic measures, directed towards breaking the cycle of infection, should be applied in all infected herds. Because of the high incidence of calfhood infection, the most important of these precautions relate to calf management.

The risk of prenatal infection renders it inadvisable to rear calves from cows known to be infected at the time of calving or which break down to the disease shortly afterwards. Apart from these, all calves born in infected herds should be removed from the mother at birth and raised in a disease-free environment for at least six months. The newly-born calf must receive colostrum during the first 24 hours of life, and this should be drawn from the dam only after thorough cleansing of the hind quarters and udder. Thereafter, all milk fed to calves should either be from known healthy cows or should be heat-treated (65° C. for 10 minutes). When calves are weaned, they should graze only pastures which have not been in recent use by adult stock. It may be taken that ground infection will persist perhaps two to three months under hot, dry conditions and up to 12 months in cooler and wetter areas.

Although susceptibility is greatest in calfhood, adult animals are not immune from infection, and whenever clinical cases of the disease are present in a herd the resulting massive dissemination of infection constitutes a danger to healthy animals of any age. Animals spreading infection must therefore be identified and removed from the herd, and steps taken to ensure, as far as possible, that ground contaminated by them is not used again by susceptible animals (especially calves) until the infection has disappeared.

The important part played in the spread of infection by contaminated water supplies has already been mentioned. Besides water in open dams, any supply which is liable to faecal contamination may become a highly potent and constant source of infection, and there can be no doubt that conditions are suitable for the development of this danger on many Kenya farms. The remedy is to fence off open dams and pipe the water to troughs, which should be constructed so as to minimize the danger of faecal contamination, and should be cleaned out regularly.

The measures so far described will be effective in reducing the incidence of the disease in any infected herd, provided they are applied rigorously and for a sufficient length of time. It is not certain, however, that such measures alone, even when applied for many years, will eradicate the disease completely.

Control Based on Blood Testing

The control process can be speeded up if a policy of elimination or segregation, based on blood testing, is adopted in addition to the hygienic measures.

By this method, the herd is divided, according to the results of complement fixation testing, into infected, doubtful and clean groups. The infected group is best eliminated forthwith, but this may be economically impossible when a heavy incidence of infection is found, particularly as a large proportion of such animals are often at their peak of production. In such a case they must be maintained in completely effective isolation from the healthy herd. The doubtful and clean groups are separated and managed in such a way as to minimize the possibility of infection passing to the clean group; the use of grazing and watering places are obviously factors requiring careful supervision.

Control based upon blood testing has several unfortunate limitations. The chief of these is that because of the lengthy incubation period early cases of the disease are not detected by the test, so that a number of infected animals are included in the clean herd. Further, non-specific reactions occur which result in some uninfected animals being assessed as doubtful and hence placed in a group containing infected animals. These disadvantages are reduced to some extent if blood testing is repeated at short intervals.

It is evident that segregation based on blood testing is an imperfect procedure. Nevertheless, it is better than no segregation at all, and in conjunction with the recommended hygienic measures the method constitutes the best available form of control. It should appeal to the owner of the herd in which Johne's disease presents an economic problem, because it is reasonably certain, even in heavily infected herds, to reduce the incidence of clinical disease to manageable proportions within a year or two. Again, however, complete eradication of the disease will not be achieved without many years of effort.

Vaccination

A vaccine is available which seems to be effective in producing a good level of immunity in young cattle. The vaccine is now the subject of large-scale experiments in the United Kingdom, and similar experiments are being conducted by the Kenya Veterinary Department to assess its value under East African conditions. Unfortunately, this vaccine causes sensitivity to the skin test for tuberculosis so that in the event of this disease appearing in a vaccinated herd, tuberculin testing would be valueless. Tuberculosis is, admittedly, rare in Kenya, but it does appear unpredictably in an occasional herd, and it is of great importance in public health. A further drawback is that vaccinated animals, being unable to pass the tuberculin test, could not be exported from the Colony. Widespread use of vaccine, therefore, would have a most adverse effect on the Colony's exports. The possibility of devising adequate safeguards to allow the vaccine to be used is under constant review by the Director of Veterinary Services.

Treatment

Several drugs elaborated in recent years have achieved remarkable success against human tuberculosis, and because of the similarities between the organisms of tuberculosis and Johne's disease, it would be reasonable to expect some of these drugs to be effective also against Johne's disease. Trials have been carried out but, so far, have proved uniformly unsuccessful; no drug has produced a cure, although temporary clinical improvement has been achieved in several cases. All of the drugs are extremely costly. One of the more promising of them is at present undergoing extensive trials in an experiment conducted by the Kenya Veterinary Department. As usual, however, in Johne's disease experiments, several years must elapse before valid results can be hoped for, and these may in the event turn out to be quite unfavourable to the drug concerned. At the present time, therefore, attempts to treat Johne's disease in individual animals cannot be recommended.

NOTES ON KENYA AGRICULTURE*

I—CEREAL CROPS

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Crop	Spacing	Seed Rate per acre	Yield per acre	Time to Maturity
		lb.		*months*
MAIZE—				
for seed ..	3′ x 1′ or 3′ x 1½′	15–20	7–25 bags.	3½–9
silage ..	Broadcast or Drilled	45	15 tons.	2–4
MILLETS—				
Bulrush ..	3′ x 2′	6	500–800 lb.	4
Finger ..	Broadcast or Drill	30	600–1,000 lb.	3–5
Golden ..	,,	30	800	2½–3
Italian ..	,,	30	600–800 lb.	3
RICE	Drilled	55–75	1½–3 tons.	4½–6
	Transplanted 6″ x 6″	25		
SORGHUM—				
Giant ..	3′ x 1½′	4–8	800–1,200 lb.	4½–6
Dwarf ..	1½′ x 9″	6–18	1,000–2,500 lb.	3½–4½
BARLEY ..	Drilled	70–80	7–15 bags.	4–6
WHEAT ..	Drilled	70–100	4–10 bags.	4½–7
OATS	Drilled	50–80	7–15 bags.	
			6–10 tons silage.	4½–6
				weeks
BUCKWHEAT ..	Broadcast	25	1,000 lb. seed	10
	Drilled	20	7 tons green manure	8
RYE	Drilled	75	4–8 bags.	*months* 5
	Broadcast			

MAIZE (*Zea Mays*) Kiswahili—Mahindi

Climate and Soils

Does best at altitudes of 4,000–6,000 ft. with up to 30 in. rainfall well distributed during the growing season. Given fertile soils and good rainfall can be grown from 0–8,000 ft. Best soils are loams with high humus level.

Cultivation

Seed should be selected from large, well-shaped cobs from healthy vigorous plants. Avoid using seed from cobs which extrude through the shuck, or show signs of disease (ear-rot). Cobs should be long, thick, with minimum taper towards the tip and preferably with 12–16 rows of grain. Sow on well-prepared seed bed at 2-in. depth in moist soil and 3–4 in. in dry conditions. When adequate rain has fallen, sow as soon as possible. Dry planting is often worth while in low-rainfall areas. Up to 1 cwt. per acre of double superphosphate may be needed on poorer soils. Good yields may be expected when maize is grown after potatoes as they are normally given a good dressing of farmyard manure. Maize also responds well to F.Y.M., particularly if this is placed in the rows prior to

* These notes are intended as a guide to agricultural officers and farmers, but it will be appreciated that the recommendations may not suit every locality. For example, rainfall requirements are given in inches per annum, but much depends on the seasonal distribution of the rainfall and on the standard of farming. The conservation of soil moisture by such practices as early weeding (to reduce losses by transpiration), bare fallowing (to retain moisture in the subsoil in order to supplement the rainfall in the ensuing season), and mulching (to prevent soil compaction and to permit rapid percolation of the rain) all help to reduce the rainfall requirements of crops as measured in inches per annum. A.H.S.

sowing. It is very important to keep down weeds, particularly during early growth of the crop.

Can form a useful nurse crop for a grass ley which can be sown after the last weeding when the maize is about 4 ft. high.

Harvesting

Harvesting should be delayed as long as possible in order to allow cobs to dry out fully on the plant. Drying in the stook allows the grain to mature more fully whilst enabling early ploughing to be undertaken. Every effort should be made to reduce the moisture content of the grain to under 12 per cent in order to reduce the risk of weevil infestation.

Major Uses

A staple food crop amongst Africans which has replaced sorghum in many areas but which, in turn, is being replaced by wheat and rice where these can be grown. The stover is a useful fodder when grass is scarce. Is an excellent silage crop grown pure or mixed with legumes. On many European farms it is grown as a cash crop, for food, for labour and stock.

BULRUSH MILLET (*Pennisetum typhoideum*) Kiswahili—Mawele

Climate and Soils

Being quicker maturing and more drought resistant, is usually grown in areas of low or uncertain rainfall and on sandy soils where maize and sorghum would be less likely to yield a crop. Altitude, 0–5,000 ft. Rainfall, 15–30 in.

Cultivation

Generally sown on the flat though may be grown on 3-ft. ridges, particularly if interplanted with groundnuts or cowpeas—a practice which should not be discouraged as there is evidence to suggest that it results in improved yields of grain.

The crop is subject to serious attacks by numerous kinds of birds, and in some districts growers break the stalks and lay them over on the ground to reduce bird damage. Awned varieties also reduce bird damage, but it is difficult to maintain a supply of pure seed on a district scale as it crosses so readily with awnless varieties and wild pennisetums.

Harvesting

By hand only as dwarf types suitable for combine harvesting cannot be produced.

Major Uses

The small, hard, pearly grey grains are immune to weevil attack and, if properly dried, can be stored in bins or tanks for as long as seven years. Stover is useful for cattle fodder.

ELEUSINE OR FINGER MILLET (*Eleusine coracana*) Kiswahili—Ulezi

An erect sedge, about 2–3 ft. high, suited to poor and rich soils, usually in upland areas. Produces a very small reddish-brown grain, which is capable of prolonged storage, makes a very nutritious porridge and is popular for brewing native beer.

Seed sown broadcast, often on poor land which has previously been subjected to burning of all vegetation. Seed rate about 30 lb. per acre. Crop matures in three to five months and yields 600 to 1,000 lb. per acre. Attacked by birds.

GOLDEN MILLET (*Panicum miliaceum*) Kiswahili—Uwele

An erect annual grass. 2–3 ft. high and open drooping panicle. Suited to low rainfall areas owing to rapid maturity (2½–3 months) and low water demand. Yields 800 lb. grain per acre. Grain stores well and produces palatable porridge. Easily harvested by combine. Subject to bird attack. Seed shatters readily when ripe.

ITALIAN MILLETT (*Setaria italica*) Kiswahili—Kimanga or Mawele manga.

Annual grass, 2–3 ft. high, bearing cylindrical spike-like panicles with a smooth grain. Useful in dry areas, as it produces a nutritious grain. Yield 600–800 lb. per acre. Attacked by birds.

RICE (*or* PADDY) (*Oryza Sativa*) Kiswahili—Mpunga

Climate and Soil

There are two main types of rice:—

(*a*) Swamp rice grown under irrigation or in swampy depressions, e.g. Mwea Tebere and Hola Irrigation Schemes; Kano Plains and western areas of Central and North Nyanza.

(*b*) Hill rice which can be grown under semi-dry land conditions in "hanging swamps", e.g. Mumias area of North Nyanza.

Both types are unlikely to succeed above 5,000 ft. in East Africa and generally prefer lower altitudes with high temperatures and either ample rainfall or irrigation water.

Cultivation

Seed may be sown in seed beds and the seedlings transplanted into bunded fields or the seed may be sown direct into the fields, either by broadcasting or drilling. The seed rate is about 15 lb. per acre (of transplanted field) for transplanting at 12 × 6-in. spacing, 30 lb. at 6 × 6-in. spacing, while for drilling it is 56 lb. or more, and for broadcasting about 112 lb. In general, for swamp rice, transplanting is to be recommended under peasant conditions in East Africa as yields are usually higher than with direct sowing, irrigation water is economized because of the shorter time the crop is in the field, and weed control and roguing are much easier. The disadvantage of transplanting is its high labour requirement.

Seed should be at least six weeks old before sowing. It should be pregerminated by soaking in water for 24 hours, then keeping under damp sacks for a further two or three days, then sown broadcast in the nursery, which should be well puddled and dead level but with little or no standing water. A little water may be added when the seedlings are established. Transplanting into a carefully levelled field should take place when the seedlings are 8–10 in. high, this stage being usually reached after four to six weeks. If fertility is low, 6 × 6-in. spacing may be adopted, but 9 × 9 in. or 12 × 6 in. are generally to be preferred as rice usually tillers profusely in East Africa. From one to three seedlings may be planted per clump. Planting should be as *shallow* as possible in the mud as this promotes good early tillering upon which a high yield depends. If the seedlings are large, the tips may be cut off before transplanting. Any spare seedlings can be planted in a large clump in a corner for "gapping-up" the field after a few days.

Depth of water should be maintained at about 3 in. If deeper than this, early tillering is reduced, while if too shallow, weed suppression is less effective. This, of course, presupposes good levelling before planting. A slow movement of water through the field is usually considered beneficial but is not justified where water is limited or expensive. Early inter-row cultivation by Japanese weeder or claw hoe is also beneficial, as, apart from weed control, stirring the mud promotes aeration of the roots and good early tillering. The water should be drained from the field when most of the grain is passing from the milky to the cheesy stage, some three to four weeks before harvesting. Bird damage can often be severe at this period unless adequate bird scaring is done. Rogues, especially red-grained plants, must be pulled up, otherwise the crop may well be unsaleable under present market conditions.

Harvesting should be done slightly before the crop is dead ripe to reduce loss from shattering (and perhaps birds) and reduce the risk of grain cracking. A crop required for use as seed should, however, be left until dead ripe before being harvested.

Harvesting

Cutting of peasant crops is usually done by sickle. It is most important that no more should be cut in one day than can be threshed that same day. This is to avoid the risk of grain cracking, the commonest cause of which is alternate wetting and drying of ripe grain, by dew at night for example. For this reason stooking, unlike other cereals, is quite inappropriate with rice. If any cut rice has to be left out it should be made into a small stack but not stooked. Likewise, threshed grain should be well protected from dew at night.

Complete mechanization of rice harvesting by combine harvester is possible where the acreage is large and the fields are big and easily accessible and the ground dry. The crop should, however, be erect, close planted, with few tillers, comparatively non-shattering, even ripening, and as free as possible from green material in the straw. In general, varieties specially selected or bred for combining are necessary. Partial mechanization, say by mower or binder and mechanical thresher is difficult with rice because of its tendency to shatter and its short, weak straw.

Major Uses

The peasant rice grower may hull his crop in small quantities and use as food as is done by many African growers in Tanganyika or, alternatively, he may grow rice as a cash crop. For the latter purpose, good quality must be

insisted on if an economic price is to be obtained or, indeed, if the rice is to be saleable at all. The position to-day is that attractive, highly polished, imported rice is readily available to the Indian consumer in East Africa so the locally grown product must be of equal or higher quality to have any hope of competing. The main aspects of quality for the East African market are: (1) A long, thin white grain without any admixture of broad grains or red grains; (2) absence of cracked grains which result in excessive broken grain in milling.

The products of milling, apart from whole rice and brokens, are husk, bran and polishings. The husk is of little value but is used as fuel at some rice mills. The bran and polishings comprise the various layers of seed coat and possess a high nutritive value for stock feeding. Small rice hullers, unfortunately, do not separate the bran and polishings from the husk and the mixture can only be fed very sparingly on account of the high silica content of the husk.

The nutritive value of the milled rice itself depends on the degree of polishing because almost all the protein, oil and vitamins are contained in the embryo and the seed coat surrounding the starchy endosperm. Beri-Beri disease of the Far East is caused by a lack of vitamin B resulting from a diet of highly polished white rice insufficiently supported by other foods. Parboiled rice, however, has a higher food value because some of the constituents in the outer layers of the grain pass into the endosperm during the parboiling process which precedes milling.

SORGHUM (*Sorghum vulgare*)
Kiswahili—Mtama

Climate and Soils

Requires similar soil conditions to maize but will withstand heat and drought better.

Cultivation

Spacing varies with size of plant and may be from 15–42 in. between rows and 9–15 in. in the row. Seed rate 6–18 lb. per acre. Deep rooting and capable of utilizing soil moisture to depth of 5 ft. and therefore useful in low rainfall areas. Use press wheel or light roller behind planter to compact earth round seed in order to promote rapid and even germination—an important point in semi-arid areas as it extends planting period by as much as a week.

Harvesting

Height varies from 2½ ft. to over 20 ft. Tall growing types by hand. Dwarf types by combine harvester provided even height of crop is obtained. Crop often attacked by American bollworm (*Heliothis armigera*) which can reach devastating proportions unless dusted immediately with BHC/DDT mixture as for cotton. A useful silage crop and stover is useful fodder for livestock. Readily attacked by birds though some varieties with a bitter seed coat are resistant to attack. The soft-grained heavy yielding types deteriorate rapidly in storage unless thoroughly treated. The hard-grained "Shallu" types keep well but generally yield less than the soft-grained varieties. In areas of high rainfall, open-headed types are less likely to suffer from fungal damage to the grain prior to harvesting.

Major Uses

Staple cereal for Africans. Also used for breakfast cereals, and partial substitute for maize in livestock rations. Commonly used for brewing native beer and was used for European bottled beer during the last war when barley was in short supply. The sprouted grains make an excellent addition to livestock rations.

BARLEY (*Hordeum sativum*)
Kiswahili—Shayiri

Climate and Soils

Requires a cool climate with not less than 20 in. rainfall during the growing period of the crop. Uninterrupted growth and natural ripening are essential for the production of a good malting sample. Wet, *vlei* lands must be avoided and a medium to light well-drained soil is best. Minimum altitude is 6,500 ft.

Cultivation

A profitable return can be assured if cultivation, manuring, seeding and varietal selection are carefully attended to. Best quality and quantity obtained when grown after one or two crops of wheat. A good crop to grow before the grass leys (which can be undersown provided a light barley seeding rate is used). A fine seed bed is required. 100 lb. of double superphosphate applied at time of planting is usually desirable.

The following table may be of help in choosing a suitable variety:—

	Malting	*Feeding*
Moist conditions	Research, Proctor and possibly No. 5	Herta, Heimdal, Kenia Carlsberg
Dry conditions	Research	Prior

Essential to sow good, clean, pure seed of high germination percentage. Mixed seed ripens unevenly. Seed should be dressed to control barley fly and various diseases prevalent in Kenya. To produce the best malting samples sowing should be arranged so that the last weeks of ripening occur during the humid weeks following the rains in order to produce a bright-coloured, plump, uniform sample having a mealy rather than steely grain.

Harvesting

Essential to harvest only fully ripe grain if malting sample is required. Green patches in shade or near fences should be excluded. Avoid setting the combine drum too close to avoid skinning the grain and damage to embryos.

Major Uses

The best quality malting barley is used for brewing beer. The ordinary types are an important ingredient in rations for livestock, particularly pigs.

WHEAT (*Triticum vulgare* and *Triticum durum*)
Kiswahili—Ngano

Climate and Soils

A major cereal crop of the Highlands particularly in the higher country. Limited production also occurs near Mount Kenya and in the Northern Province of Tanganyika; in both these areas two crops are grown each year. Usual range is 6,000–9,000 ft. with better yields in the medium to high altitudes.

Cultivation

Wheat is one of the main crops of European farming and, although the acreage has tended to diminish recently, due to various reasons, it forms a basic part of balanced rotational farming in most areas. Wheat monoculture is bad for the soil and in the higher country soon builds up heavy infections of Take-all disease.

The chief limitations to wheat growing are rust susceptibility, of which the most important is stem rust; but yellow rust also does damage above 7,000 ft. both to leaves and ears. The choice of varieties largely depends on these two diseases; the latest recommendations should always be sought in view of the rapid changes which occur in the races of rust and the availability of varieties. The seed bed should be thoroughly prepared and free from weeds; if excessive weed growth appears in the crop there are suitable sprays available to control most of them. The use of phosphate fertilizer is almost always required, and in most of the higher country is absolutely essential. Dressings of about 1–1½ cwt. of double superphosphate are normally used, or equivalent. A seed dressing is also now current usage; various brands are available but the need is for a combined protection against fungal diseases and insect pests. Sowing rates vary from 70 to 100 lb. according to altitude and soil condition, and also, to some extent, according to the variety itself.

Harvesting

By combine harvester; the seed is then cleaned by winnowing or by a special cleaner.

Major Uses

The flour of *Triticum vulgare* is used mainly as bread; the flour of *T. durum* is used for macaroni and also in the production of "Atta". Milling offals are valuable components of stockfeeds, and the straw is used for litter, bedding and mulching.

OATS (*Avena sativa*)

Climate and Soils

Well suited to cool, dull, rainy areas. Needs comparatively little sun for ripening. Can be grown satisfactorily on wet *vlei* land for both silage and grain, but the best quality of grain is produced under drier conditions. A useful crop to sow after breaking natural *veldt,* when it is often grazed off in the first year and grown for grain in the second year.

Cultivation

Plough *vlei* land as soon as possible after the rains with inverted furrow slice to bury the grasses. Plough again when grasses appear in the furrows and then disc until a "cobbly" tilth is obtained. Avoid a fine tilth, especially on *vlei* soils. 60–70 lb. of double superphosphate may be applied with profit. The best varieties for conditions in Kenya are *Lampton* for silage or feed grain and *Grey Algerian* for milling oats. To avoid losses

from various diseases, the seed should always be treated with an organo-mercurial dressing before planting. The use of a Cambridge roller assists in controlling cutworm. Oats should not be undersown with a ley unless it is cut early for silage as the vigorous growth of the oats smothers the ley.

Harvesting

Considerable loss can occur if the crop is cut when dead ripe. The crop is not eminently suited to harvesting with a combine. Early cutting with a reaper binder and final ripening in the stook is probably the best method of harvesting. For silage the crop should be cut when the first heads start shooting. For hay, oats should be cut in the early milky stage to obtain maximum bulk with quality.

Major Uses

Best quality milling oats are used for porridge. Used as grain feed for horses, cattle and sheep, but usually too expensive. Unsuitable as a major constituent for pig feed owing to high per cent crude fibre. Interchangeable with maize in preparing rations. The straw is useful for fodder.

BUCKWHEAT (*Fagopyrum* sp.)

Climate and Soils

Suited to a moist, cool climate and will grow at a higher altitude than majority of cereals. Does best on sandy, well-drained soils. Whilst it responds to good soils it can be grown successfully on poor land. When sown as a mixture with lupins it is useful for improving poor soils.

Cultivation

As a green manure or cover crop it is sown at the beginning of the rains, but when seed is required, planting is delayed to enable it to mature in the dry season. May be sown broadcast or drilled in rows 12–15 in. apart.

Harvesting

As a green manure it is ready in eight weeks. For seed the crop should be harvested after 10 weeks when the seeds at the bases of the plants are fully ripe. Delay in reaping results in losses from shedding. Plants should be cut during dull weather or in the morning before they are quite dry. The crop should be stooked loosely in the field to dry, and threshed *in situ* on tarpaulins. Avoid stacking as the crop heats very readily.

Major Uses

Green manure and smother crop, human consumption, poultry feed and a substitute for oats in rations for horses, pigs and cows. The crop may be grazed young but is dangerous when mature.

RYE (*Secale ceriale*)

This crop is scarcely ever grown in Kenya owing to heavy losses from stem rust.

REVIEWS

A CRITICAL REVIEW OF THE TECHNIQUES FOR TESTING INSECTICIDES, by J. R. Busvine, published by the Commonwealth Institute of Entomology, London, 1957, X + 208 pp. 50 figs., 551 refs., price 30*s*.

The subject of this review, though specialist, is becoming the concern of more and more people as the quest for higher productivity and quality in agriculture continues. Dr. Busvine, after dealing with the general principles involved, continues with the handling and standardization of the insects themselves which are to be used for testing insecticides and repellents. In further chapters techniques for the assaying of stomach poisons, contact poisons, sprays, fumigants and repellents are reviewed. Finally, there is a section devoted to the special brand of statistics used in evaluating toxicological studies.

I.W.B.N.

THE GRASSLAND AND FODDER RESOURCES OF INDIA, by R. O. Whyte, published by the Indian Council of Agricultural Research, New Delhi, India, 1957, 437 pp., price 36*s*.

The author, who is on the staff of F.A.O., prepared this book during an assignment to India under the Expanded Technical Assistance Programme of F.A.O., in collaboration with ten Indian specialist officers. It is a summary of the available information on the subject, and the 17 chapters contain 50 plates and 15 maps. They cover the agricultural, land use, and economic aspects of grassland resources and fodder production in India, and there is a comprehensive list of references to publications from which the book was compiled.

D.W.D.

NOTES ON KENYA AGRICULTURE

II—TABULATED RECOMMENDATIONS FOR MANURING AND FERTILIZING IN AFRICAN AREAS

By E. Bellis, Department of Agriculture, Kenya

These recommendations are based on experimental results obtained to date and may be modified as a result of further trials.

GENERAL ARABLE CROPS

(Rates per Acre)

CENTRAL PROVINCE

	Bracken Zone	*Kikuyu and Star Grass Zone*	*Woodland Zone*
Potatoes ..	2 cwt. double supers and 15 tons FYM.	2 cwt. double supers and try 2 cwt. sulphate of ammonia.	No recommendation.
Maize ..	Fertilising not justified.	1 cwt. sulphate of ammonia where rainfall good and particularly on exhausted land and 1 cwt. double supers.	No recommendation.
Legumes ..	Fertilising not justified.	—	No recommendation.

NYANZA PROVINCE

	Red, dark red brown and orange loams	*Red sands and sandy loams*	*Deep pallid sands*	*Shallow pallid loams over murram*	*Sotik Parklands*
Root Crops	2 cwt. double supers.	No recommendation available.	No recommendation available.	15 tons FYM 2 cwt. double supers and 2 cwt. sulphate of ammonia.	2 cwt. double supers.
Cereals ..	1 cwt. double supers.	1 cwt. double supers and 1 cwt. sulphate of ammonia.	1 cwt. sulphate of ammonia.	7½ tons FYM 1 cwt. double supers 1 cwt. sulphate of ammonia.	1 cwt. double supers.
Other Crops	1 cwt. double supers.	No recommendation available.	No recommendation available.	No recommendation available.	1 cwt. double supers.

SOUTHERN PROVINCE

	Dark red sandy loams with good rainfall	*Pallid and orange sands with unreliable rainfall*	*Light red sands sandy loams and Mangalata*	
			With good rainfall	*With unreliable rainfall*
All Crops ..	Fertilising not justified.	Fertilising not justified.	—	—
Maize ..	—	—	1 cwt. double supers.	Fertilising not justified.
Bulrush Millet	—	—	1 cwt. double supers.	1 cwt. double supers.

RIFT VALLEY PROVINCE

	Red brown loams	*Orange and red sands and sandy loams*	*Red loams*
Roots	2 cwt. double supers and 15 tons FYM.	Try 2 cwt. sulphate of ammonia and 2 cwt. double supers.	Try 2 cwt. double supers.
Other Crops ..	Try 1 cwt. sulphate of ammonia and 1 cwt of double supers.		Try 1 cwt. double supers.

COAST PROVINCE

	Red and orange sands in coastal hills	*Lagoonal sands*
Cereals	1 cwt. double supers.	Fertilising not justified.

Note.—Fertilizers and manure for *potatoes* should be applied in the furrow before planting and covered by splitting the ridges. Phosphates for *seeded crops* should be band applied in the rows preferably below and separated by a thin layer of soil from the seed.

Nitrogen for *cereals* should be top dressed in bands along the crop rows during a period of active growth. With fertilizer and manure application must go careful land preparation, timely planting and effective weed, pest and disease control.

Coffee

Seedling Beds

Heavy manure dressing.

Planting Holes

One to three *debes** manure or ¼–½ lb. basic slag per hole according to size of hole.

Three Weeks After Planting

Two ounces sulphate of ammonia per tree near stem.

One Year Old

Two *debes* manure early in rains and 2-4 oz. sulphate of ammonia per tree three weeks later.

Two to Three Years Old

Two *debes* manure early in rains and 2–4 oz. sulphate of ammonia or 1–3 oz. urea per tree three weeks later.

Bearing Coffee

Three ounces urea per tree per annum three weeks after start of main rains.

Fruit and Vegetables

Pineapples—Good Virgin Land

No fertilizer or manure needed.

Bench Terraces or Land in Poor Heart

At least 10 tons manure per acre during preparation, particularly at the back of the bench.

Old Pineapple Land

Spaced applications each of 3 lb. sulphate of ammonia per 100 plants in first year preferably at second, fourth, sixth and eighth month after planting and during wet weather.

Tree Fruits

Broadcast FYM annually and lightly dig in or cover with mulch over whole root zone. Apply one *debe* first year and increase by half *debe* yearly up to maximum of six *debes*. If FYM is not available substitute sulphate of ammonia at rate ½ to 3 lb. per tree according to size in two applications on top of mulch early in rainy season.

Strawberries

One *debe* manure during land preparation followed on poor land with top dressing of 2 oz. sulphate of ammonia and 2 oz. double supers per square yard.

Asparagus

One *debe* manure per 6 ft. of row in furrow before planting and annually at moulding up before cutting.

Tomatoes

One *debe* manure per 4 square yards before planting.

Mixed Vegetables

One *debe* manure per 4 square yards before planting brassicas and cucurbits and follow with root crops and salads and then legumes without further manure.

Grassland

(*Rates per Acre*)

For Ley

1 cwt. double supers and 1 cwt. sulphate of ammonia or try 2 lb. Kenya white clover (inoculated) with 1 cwt. double supers and 1½ cwt gypsum in seed bed where rainfall adequate.

Two to Three-year Ley and Productive Permanent Pasture

1 cwt. double supers and where legume absent 1 cwt. sulphate of ammonia annually.

Elephant Grass

1½ cwt. double supers annually and 2 cwt. sulphate of ammonia per cut.

* A *debe* is a four-gallon kerosene tin.

BROWSE PLANTS OF KENYA

WITH SPECIAL REFERENCE TO THOSE OCCURRING IN SOUTH BARINGO

By H. W. Dougall and A. V. Bogdan, Department of Agriculture, Kenya

(*Received for publication on 17th October, 1957*)

"It is a humbling fact for grass pasture experts to realize that probably more animals feed on shrubs and trees, or on associations in which shrubs and trees play an important part, than on true grass or grass-legume pastures, short and tall grass ranges and steppes." This introductory sentence to "The Use and Misuse of Shrubs and Trees as Fodder" (1947) is almost certainly applicable to most semi-arid and arid parts of Kenya inhabited by pastoral tribes and their livestock; it is particularly relevant to the South Baringo District, where most of the material described in this paper was collected. The southern part of the Baringo District is believed to be potential perennial grass-woodland country, but at the present time the grass cover is almost completely destroyed and the ground is exposed to such an extent that even during rainy seasons the leaves, bark and pods of trees and shrubs, together with the available herbs, provide the bulk of the diet of the ruminant and of other livestock.

The tendentious subject of the regeneration of these and other pastoral lands in similar condition is beyond the scope of this present paper, but there can be little doubt that with systematically controlled grazing, reduction in stock numbers where necessary, judicious burning and bush-thinning to allow more space for grass and greater freedom of movement for livestock, a better position could be achieved. Indeed, there is already evidence that one or more of these measures is capable of causing a marked initial restoration of a grass cover. The desirability of protecting the more valuable trees, shrubs and herbs which not only supply shade but also browse that apparently is a very useful source of protein and of minerals, will hardly be disputed. It is hoped that this survey of such plants may be of some assistance to those who are obliged to make decisions on questions of bush-clearance or on the selection of species which may usefully be cultivated under these conditions.

A botanical description of the browse plants follows, and a list of some of their tribal names is also given. The chemical composition of the browse plants is given in Table 1. Section 1 of this table is devoted to the South Baringo plants and section 2 to those collected in other parts of Kenya.

Plants of the Baringo District

*Acacia brevispica** Harms (Leguminosae)

A shrub 8–15 ft. in height with long and thin rambling branches which are covered with small numerous scattered thorns. The leaves are fairly large and the white flowers are in globose heads. The pods are thin, flat and broad. *Acacia brevispica* is common in the southern part of the Baringo District, usually in admixture with other shrubs. It occurs mostly on well-drained slopes in deep and fertile red soil. This shrub is more abundant in other parts of Kenya, mostly at altitudes from 3,500 ft. to 6,500 ft. where it often forms dense thickets. Goats browse on this bush to a considerable extent, eating the leaves, flowers and young pods. *Acacia brevispica* is seldom eaten by cattle, probably due to its very thorny branches. It is not of primary importance in the Baringo District. Separate analyses of leaves and young pods show that their nutritive value is rather similar and fairly high as the protein content is around 17–19 per cent.

Acacia gerrardii Benth. (*A. hebecladoides* Harms)

A medium-to-large tree with a dense crown which is variable in shape: it may be either flat-topped or ball-shaped or just simply irregular. It has rather large leaves and white flowers which occur in globose heads. The pods are large and sickle-shaped. This tree is common in the *Acacia-Themeda* zone at altitudes from 4,000 ft. to about 6,500 ft. It often occurs in places with slightly impeded drainage. As a browsing plant *Acacia gerrardii* is not valued highly by the Tugen. The leaves

* One of the species formerly wrongly known in Kenya as *Acacia pennata*.

are not liked by livestock and because the branches are high above the ground they are inaccessible for direct browsing; these are lopped to feed the goats and cattle, but only when more attractive browsing is not available. The feeding value of the leaves of *Acacia gerrardii* appears to be high. Our sample contained over 17 per cent of crude protein.

Acacia mellifera (Vahl) Benth.

A shrub or a small tree with a ball-shaped crown. The leaves are small, with only a few leaflets. The branches are covered with very sharp recurved thorns. The flowers are white and gathered in short, dense spikes; the pods are thin and flat. *Acacia mellifera* is very common in the southern, and partly also in the northern, parts of the Baringo District, and is often a dominant woody plant in the desert grass-bush zone at altitudes from 3,500 ft. to 4,500 ft. It is also common in many other arid parts of Kenya. Goats are very fond of the leaves which are either browsed from the standing shrubs or are picked up when they fall to the ground; this normally occurs early in the dry season. The young leaves, which usually appear in February, in the middle of the dry season, are very much liked by goats, and in the areas where *Acacia mellifera* is dominant it contributes very considerably to their diet. *Acacia mellifera* is used only by goats since cattle are unable to pick up individual small leaves, and the branches are too spiny to be eaten together with the foliage. The very young leaves which were analysed contained over 42 per cent of crude protein and only 16 per cent of crude fibre.

Acacia seyal Del.

A slender tree usually 20–40 ft. in height, with a flat-topped, thin crown and rather scarce foliage. The bark is smooth and greenish-yellow in colour; when damaged it often becomes orange-coloured. The yellow flowers are in globose heads; the pods are sickle-shaped. This tree is very common in the southern part of the Baringo District and it is also widespread in other semi-arid parts of Kenya. *Aacia seyal* occurs mostly on flat land, often with impeded drainage: it avoids steep, rocky slopes. Var. *fistula* is common at swamp edges in the areas between Lakes Baringo and Hannington. This variety differs in having more numerous thorns which arise from ant-galls. In *Acacia seyal* the bark is the most valuable part. It is extensively used for feeding cattle, goats and sheep during dry seasons. The bark is thick, smooth at the surface and relatively soft when fresh. In the dry months of February and March, thick branches are cut and thrown to the ground where the animals browse the bark and eat the leaves which are, however, relatively few at the time the bark is used. Often the whole tree is cut to a height of about 5–8 ft. In areas where *Acacia seyal* is extensively used, most of the trees are badly deformed and their branches sprout from the level at which they were previously cut. As animals often browse the bark of standing trees, these latter also become deformed and knobby, with cankerous swellings. In places where *Acacia seyal* is used intensively, many trees are beginning to die out and the amount of bark available to feed animals is becoming increasingly scarce. It is said that cattle fed mainly on *Acacia* bark will eat from 10–12 lb. per head per day and that this amount is sufficient for maintenance and even for the production of about one gallon of milk. Two samples of bark were analysed. One sample was taken from thick branches in August and another from less thick branches in February, at a time when the bark is actually fed to cattle. The February analysis gave a much higher crude protein value (10.6 per cent) as compared with the August sample (4.1 per cent). The calcium value was very high especially in the February sample (over 4 per cent), but in both samples phosphorus was very low, being under 0.1 per cent.

Acacia tortilis (Forsk.) Hayne subsp. *spirocarpa* (Hochst. ex A. Rich.) Brenan (*A. spirocarpa* Hochst. ex A. Rich.)

A medium-sized or large flat-topped tree with a moderately dense crown. The white flowers are in globose heads. The pods are ring or half-ring shaped. This tree is very common in the desert grass-bush zone at altitudes below 4,000 ft. where it occurs amongst smaller trees and shrubs. In flat alluvial valleys, mostly between Lakes Baringo and Hannington, *spirocarpa* grows tall and it often forms dense growth, particularly when close to stream-courses. Leaves of young trees, when they can still be reached, are browsed by goats and sheep, but the main value of *spirocarpa* is in its pods which are eaten by all African livestock. The pods can be very numerous and they are picked up from the ground. At the time when the pods are mature, usually in January-February, they are often the main source of food for cattle, sheep and goats in

the alluvial valleys, and they contribute considerably to the diet of animals living outside the flats. The ripe pods, together with the seed they contain, are rich in protein (17.8 per cent) and in calcium (1.2 per cent) and low in fibre. Pods of *Acacia spirocarpa* from Tanganyika (French, 1943) contained 12.6 per cent of crude protein.

Acacia nilotica (L.) Del. subsp. *subalata* (Vatke) Brenan (*A. subalata* Vatke).

A small tree 8–15 ft. in height with a dense, mushroom-shaped crown which provides dense shade. The yellow flowers are in numerous globose heads. The pods are thick, greyish-green in colour and fleshy when young, becoming black and hard at maturity. This tree is widespread in Kenya, mostly at altitudes from 3,000 to 6,500 ft. It is fairly common and often numerous in the southern part of the Baringo District. The fleshy pods are readily eaten by goats, sheep and cattle, but the Tugen regard the pods as harmful to animals. They are believed to cause bloat. *Subalata* as a fodder tree is therefore unpopular amongst the local Africans. The leaves of young trees are browsed occasionally by goats. The nutritive value of the leaves, as indicated by analysis, is fairly good; crude protein amounts to nearly 12 per cent and crude fibre is not high, 21.35 per cent. The pods are of about the same nutritive value.

Acacia nubica Benth. (A. orfota auctt. omn. non Schweinf.)

A rather grey-green multistemmed bush to about 10 or 15 ft., rather obconical with very spreading branches. Thorns $\frac{1}{2}$–$\frac{3}{4}$ in., straight. Flowers in globose heads, greenish or yellowish. The pods are very characteristic, straw-coloured, moderately thick and with very conspicuous marginal wings quite unlike any other species. Some collectors have stressed the evil smell emanating from the cut branchlets, but others have not noticed it. *Acacia nubica* is an important browse shrub in the South Baringo District. It occurs on the alluvial silt and during the dry season, leaves and pods are available for consumption. The leaves are very rich in protein and are not at all fibrous. The pods are well provided with protein but are very fibrous. Both the leaves and the pods are rich in calcium but the former are more adequately supplied with phosphorus.

Achyranthes aspera L. (Amaranthaceae)

A perennial herb with long spikes of small, dullish pink flowers and numerous "seeds" which adhere easily to clothing. It is widespread in the Baringo District as well as in many other parts of Kenya. *Achyranthes aspera* occurs in bush and at forest edges, usually in light shade. Leaves and branches are browsed by cattle and goats throughout the year. The feeding value of *Achyranthes aspera* is very high, crude protein amounting to over 26 per cent of the dry matter. Crude fibre is relatively low.

Albizia amara (Roxb.) Boiv. (Leguminosae)

A tree 10–20 ft. in height with a wide, dense crown. The white flowers are in globose heads which are often extremely numerous and, at flowering time, which occurs in January-February, the crowns are white and resemble cherry trees in full blossom. In the southern part of the Baringo District, at altitudes above 3,500 ft., *Albizia amara* is very common and often numerous. Leaves of this tree are eaten by cattle, goats and sheep from lopped branches. They are not particularly well liked by these animals and so the trees are lopped only when more palatable fodder is not available. The flowers are liked better than the leaves, and goats either pick them from the ground after they are shed or eat them from the lopped branches. Both leaves and flowers appear to have a high feeding value. The crude protein contained in both leaves and flowers was over 26 per cent of their dry matter. Crude fibre is not particularly high, though it is less in the flowers than in the leaves.

Balanites aegyptiaca (L.) Del. (Simaroubaceae)

A small or medium-sized tree 12–18 ft. in height with characteristically recurved spiny branches, and fleshy succulent leaves. This tree is common in the Baringo District at medium or low altitudes. It prefers flat land with slightly impeded drainage, although it is also found occasionally on well-drained slopes. The fleshy leaves are eaten avidly by goats and these animals also pick up the fallen fruits which resemble dates. Cattle eat young branches only in dry seasons when other food is very scarce. Although the branches are spiny, the young twigs are eaten together with the leaves and spines, since the latter are relatively soft when young. The crude protein content of the young branches, as eaten by goats, is very high and the crude fibre content is relatively low.

Boscia angustifolia A. Rich. (Capparidaceae)

A medium-sized tree, 12–20 ft. in height, with white bark on the trunk and a dense,

often ball-shaped, crown. The shape of the crown, however, is not natural and is a result of frequent lopping of branches to feed cattle and other animals. As virtually all *Boscia angustifolia* have been lopped at various times, the naturally shaped crown, which is cylindrical, is not easily found. The branches are very leafy with very numerous, rather small leaves which are thick, fleshy and hard. This tree flowers profusely, usually in July or August. The flowers are white and have a strong scent. *Boscia angustfolia* occurs scattered over considerable areas in the semi-arid part of the Baring District from under 3,000 ft. to over 5,000 ft. altitude. It is extensively used in the dry season for feeding cattle, goats and sheep, and is of considerable importance to the local stock owners. The branches are lopped and the animals eat the leaves and young twigs on the ground. The fruits are said to be edible. Young branches with leaves have a high protein content though they are somewhat fibrous.

Cadaba farinosa Forsk. (Capparidaceae)

A shrub 3–7 ft. in height, much branched, with numerous small, greyish-green leaves. The flowers are greenish-yellow; they are fairly conspicuous because of the numerous long stamens. This shrub occurs in semi-arid and arid areas in the desert grass-bush zone, usually below 4,000 ft. altitude, where it is common and often numerous. Cattle and goats eat the leaves and young branches throughout the year, though not excessively. In dry seasons *Cadaba farinosa* is used more extensively by all classes of stock. Young branches with leaves, as eaten by the animals, contain over 18 per cent of crude protein and 27 per cent of crude fibre.

Celosia anthelmintica Aschers (Amaranthaceae)

A large trailing or climbing herb with long spikes of numerous small white flowers which have a strong sweet scent. It occurs occasionally in the southern part of the Baringo District, in places with favourable moisture conditions. All parts of this plant—stalks, leaves and flowers—are eaten by cattle, sheep and goats. The leaves are used by the Tugen as a vegetable. Analysis of the whole plant in full blossom indicates that *Celosia anthelmintica* is a useful fodder plant.

Croton dichogamus Pax (Euphorbiaceae)

A much-branched shrub, 4–8 ft. in height, with thin twigs and numerous leaves which are silvery underneath and brownish on the upper surface. "The leaves are pleasantly scented when crushed" (Battiscombe, 1936). This shrub is very common in the southern part of the Baringo District; it occurs mostly on rocky ground and occasionally also on deep red soil. Over large areas *Croton dichogamus* is a subdominant shrub in woodland where it is often the main species in the shrubby undergrowth. The leaves which fall from this shrub to the ground are eaten by goats, though to a lesser extent they may be browsed from standing plants. The nutritive value of *Croton dichogamus* for goats seems to be high, the leaves containing 25 per cent crude protein.

Fagara chalybea (Engl.) Engl. (Rutaceae)

A tree 20–30 ft. in height with a broad, dense crown. The trunks and branches are covered with large recurved spines. The leaves are large, pinnate, with the petiole bearing a few recurved spines. This tree occurs scattered in moderately dry areas of the Baringo District at altitudes from 3,500 ft. to almost 6,000 ft.; it is also common in other parts of Kenya. *Fagara chalybea* rises above the bush level and is often a prominent feature in woodland. Although the leaves are scented and according to Battiscombe "are hot to the taste" they, and the fruits, are eaten by goats throughout the year, provided that the rather highly placed branches are accessible. In dry seasons the fallen leaves are eaten by cattle. The branches are sometimes lopped and fresh leaves are then eaten from the ground. Analysis shows a satisfactory feeding value for *Fagara chalybea* leaves.

Grewia bicolor Juss. (Tiliaceae)

A much-branched shrub 6–12 ft. in height. The numerous leaves are silvery-white in colour underneath. The flowers are yellow. This shrub is very common in semi-arid areas of Kenya, including the Baringo District where it occurs at altitudes from 3,500 to 6,000 ft. in various types of bush, often on rocky ground. The leaves and young branches are reputed to be very palatable to cattle and goats and the leaves are eaten throughout the year. They contain over 12 per cent of crude protein and are not fibrous.

Grewia kakothamnos K. Schum.

A shrub 6–10 ft. in height with rather harsh leaves. The flowers are white or slightly pink. This plant occurs scattered at medium altitudes in moderately dry areas. Only goats eat the dry, fallen leaves during the dry season. The feeding value of the young branches and leaves is not high since they are fibrous and contain only 8.7 per cent of crude protein.

Hibiscus lunariifolius Willd. (Malvaceae)

An erect perennial herb with medium-sized to large leaves and large yellow flowers. It occurs occasionally in the southern part of the Baringo District, usually near the stream-banks in riparian bush where it forms extensive colonies. Young branches and leaves are eaten by goats. The protein content of the branches together with the leaves amounted to 17.8 per cent of the dry matter and the crude fibre content to over 37 per cent of the dry matter.

Justicia exigua S. Moore (Acanthaceae)

A perennial herb up to 2 ft. in height with white flowers. It is very common and numerous in moderately dry areas at altitudes of 3,500 to 6,000 ft. It occurs mostly in bush on rocky ground where it is better protected from grazing animals. This plant is highly palatable to all classes of livestock and is eaten as soon as the fresh shoots appear. Therefore, it is only under dense and spiny bush that it attains its normal height and vigour. *Justicia exigua* contributes considerably to the browse available, especially during the wet season. The feeding value of this herb seems to be fairly high, having 14 per cent of crude protein and only 22 per cent of crude fibre in its dry matter.

Justicia sp.*

A tall erect perennial herb with numerous stems, slightly succulent greyish-green leaves and dullish-mauve flowers. It is common in the southern part of the Baringo District. The plant is avidly eaten at all seasons by all classes of livestock and it is usually found in the form of low, dwarfed shrubs because the young growing shoots are permanently trimmed by grazing. It is only when it is protected from cattle and goats that it grows tall, reaching a height of 4–6 ft. This herb is under trial as a fodder plant at Giosamoi (near Solai) and is is reported by Edmondson (1957) that the results of this trial so far are good. The nutritive value of this species of *Justicia* would appear to be satisfactory; it contains over 15 per cent of crude protein, and the relatively high value of 34 per cent crude fibre.

Leucas microphylla Vatke (Labiatae)

A perennial herb up to 2½ ft. in height with white flowers. It occurs frequently in moderately dry parts of the Baringo District, usually above 3,500 ft. altitude, in bush, often on rocky slopes. This herb is very palatable at all seasons to all classes of stock and, since it is permanently browsed, it usually becomes dwarfed. Only under the protection of dense spiny bush can *Leucas microphylla* attain its normal vigour. This herb is readily eaten. It contains slightly more than 11 per cent of crude protein and is well supplied with calcium and phosphorus.

Phyllanthus guineensis Pax (Euphorbiaceae)

A shrub 4–10 ft. in height with numerous thin branches and very numerous small leaves. Its greenish-yellow, small flowers are very numerous. This shrub is common and often numerous in moderately dry or moist areas usually above 4,000 ft. altitude. It is very palatable, and cattle and goats eat the fresh leaves together with the branches. In the dry season, dry fallen leaves are picked up by goats from the ground. Analysis of a sample of branches together with leaves would appear to indicate that *Phyllanthus guineensis* is a good source of calcium and phosphorus but a poor source of crude protein. The sample analysed is also extremely fibrous.

Rhus natalensis Bernh. ex Krauss (Anacardiaceae)

A large shrub or a small tree with leafy branches. The flowers are small, greenish in colour, and gathered in large panicles. The numerous small fruits are succulent when young, becoming dry at maturity. This plant occurs scattered in woodland at altitudes over 4,300 ft. Leaves of the lower branches are eaten at all season by goats and occasionally by cattle. In dry seasons the branches are sometimes lopped and fed to cattle, goats and sheep. Young fruits, which have a sour taste, are also readily eaten. The

* This species could not be identified as the genus *Justicia* requires a revision. A specimen of it has been deposited at the Kew Herbarium under No. AB 4461.

crude protein content of the young branches with leaves and of the young fruits is 9 and 11 per cent respectively and the crude fibre content 20 and 25 per cent respectively. The fruits are slightly richer in protein and in phosphorus than the leaves, but the latter are better supplied with calcium.

Sida schimperiana Hochst. ex A. Rich. (Malvaceae)

A dwarf shrub 6 in. to 2 ft. in height with short, hard branches, small leaves and yellow flowers. This shrub is widespread in Kenya at altitudes from about 4,000 ft. to almost 9,000 ft. At high altitudes, where *Sida schimperiana* invades valuable grazing land, it is regarded as an undesirable pasture weed (Edwards and Bogdan, 1951). However, in denuded parts of the Baringo District, where grazing is very scarce *Sida schimperiana* is a useful plant which provides some additional grazing for goats and sheep. Analysis of the young branches with leaves shows that though somewhat fibrous, these materials contain a fairly high percentage of crude protein, a high percentage of calcium and adequate phosphorus.

Solanum incanum L. (*Solanaceae*) Sodom apple

A small shrub or perennial herb usually 2–5 ft. in height. The leaves are rather large and are densely covered with short hairs. The yellow, globose berries are about 1 in. in diameter. This shrub spreads by creeping rootstocks which send out numerous shoots aboveground. *Solanum incanum* is common in the Southern Baringo and in many other parts of Kenya, where it is regarded as a serious pasture weed (Edwards and Bodgan, 1951). Cattle and sheep do not touch this plant, but goats eat the leaves when no better browsing is available, although "Sodom apple" is believed to be poisonous. The leaves of this plant are very rich in crude protein and in calcium, and they are not fibrous.

Tarchonanthus camphoratus L. (Compositae)

A tree or a large shrub up to 15 ft. in height with numerous bluish-grey, fairly large leaves. The dullish-yellow flowers are in dense panicles which are more conspicuous at maturity, when they become white. This tree is very common in the southern and south-eastern portions of the Baringo District and in many other parts of Kenya. "Leleshwa" often forms pure or almost pure stands over considerable areas. The ground in "Leleshwa" woodland is often bare and in such areas (e.g. near Mugurin) cattle and goats live largely on its leaves, even though these leaves are not considered to be very much liked by these animals. Goats eat the dry leaves from the ground as well as the young, fresh leaves from the lower branches of standing trees. In dry seasons the branches are lopped and fed to animals from the ground. The leaves of "Leleshwa" contain over 11 per cent of crude protein; they are slightly aromatic and it is not surprising that ether extractives should amount to 6.7 per cent of the dry matter. "Leleshwa" leaves are a fair source of calcium but a poor source of phosphorus.

Terminalia brownei Fres. (Combretaceae)

A tree 15 ft. to over 30 ft. in height with a broad crown. The leaves are of medium size and resemble those of the plum tree. The dry fruits have two large wings which are purple before they mature. This tree occurs scattered in bush and it is prominent in the *Combretum-Hyparrhenia* and *Acacia-Themeda* zones, down to about 4,500 ft. altitude. *Terminalia brownei* is important for dry season feeding. Cattle, goats and sheep are obliged to pick up fallen leaves from the ground since the branches are too high to be reached by these animals. The branches are also lopped to make their fresh leaves available and, at certain periods, young pods are fed to animals. The bark of lopped branches is said to be eaten by cattle and goats. The young branches with leaves are low in crude protein, crude fibre and phosphorus, but rich in calcium. The young branches with leaves and young pods are a much better source of protein.

Trianthema pentandra L. (Aizoaceae)

A perenial semi-prostrate or prostrate herb 6 in. to 2 ft. in height with slightly succulent leaves and rather inconspicuous flowers. In the southern Baringo it occurs occasionally on flats with *Acacia seyal* but it is more abundant on alluvial soil nearer to Lake Baringo. This plant is reported to be extensively eaten by all kinds of livestock and it is said to be palatable at all seasons. It is worthy of trial as a cultivated fodder plant for dry areas and also for reseeding denuded alluvial soil. A similar species is common around Lake Elmenteita on soils rich in soda where it is well liked by cattle. *Trianthema pentandra* is a good source of protein and calcium and it is not fibrous.

Withania somnifera Dunal. (Solanaceae)

A perennial herb 2–4 ft. in height with numerous small flowers which, at maturity, produce red berries hidden in inflated calyxes. In southern Baringo it occurs in the areas of better rainfall, on roadsides and in bush. Goats eat the leaves, not to any appreciable extent but rather as a last choice. *Withania somnifera* is reputed to be poisonous to livestock, but disregarding its suspected poisonous properties it is well supplied with crude protein, calcium and phosphorus, and it is by no means fibrous.

Ziziphus mucronata Willd. (Rhamnaceae)

A tree 15–35 ft. in height. The branches are pendent and covered with small recurved spines. This tree occurs occasionally, mostly on stream banks. Goats and cattle eat the fallen leaves from off the ground and the branches are sometimes lopped and fed to cattle. The red berries which are often very numerous are readily eaten by goats from the ground. Analysis of the young twigs with leaves shows a fairly high content of crude protein and a very low content of crude fibre. Calcium is outstandingly high.

Plants from Other Parts of Kenya

Hypericum lanceolatum Lam. (Hypericaceae)

A shrub 5–12 ft. in height with yellow flowers. It is common in Kenya at altitudes over 7,000 ft. in bush, at forest edges and on roadsides. The leaf of this plant is a good source of protein and of calcium.

Portulacaria afra. Jacq. (Portulacaceae)

A succulent shrub 2–5 ft. in height. It is a native of South Africa and is cultivated experimentally in Kenya in dry areas as a fodder plant. At Kitale it is out of its optimum environment since it thrives better under drier conditions. Analysis of young plant material shows that it is a good source of calcium, but that it is not a particularly good source of protein.

Some Tribal Names of Plants

Botanical Name	Swahili	Tugen	Kamba	Masai
Acacia brevispica	Mwarare. Kikucha cha paka.	Garnista.	Mukuswi.	Ol Girigiri.
Acacia gerrardii		Sebeldit.		Ol Debbe. Elwai.
Acacia mellifera	Kikweta.	Ngororet.	Muthia. Kithea. Ngoja kidogo.	Oete.
Acacia seyal		Lelnet.		
Acacia tortilis	Mgunga.	Sietsiet.		Ol Gorete.
Acacia nilotica	Mgunga.	Chembiuwet.		Ol Erbat.
Achyranthes aspera	Meno-ya-nyoka.	Chesirimit.	Lusayi.	Ol Tworowi.
Albizia amara		Gotutwet.		
Balanites aegyptiaca	Mkonga. Mjunju.	Ngoswet.	Mulului.	Ol Ngoswa.
Boscia angustifolia		Lito.		
Cadaba farinosa	Kibalazi mwitu. Mvunja fumo.	Birirwet.		Malomoge.
Celosia anthelmintica		Kaiyilaigechor.		
Croton dichogamus		Kelelwa.	Mwarula.	Ol Logerdangoi.
Fagara chalybea		Kokianget.	Mukenia.	
Grewia bicolor	Mkone.	Sitewet.	Muloua. Dawa.	Ol Siteti.
Grewia kakothamnos		Timberewet.		
Hibiscus lunariifolius		Kiptulvit.		
Justicia exigua		Kelemondet.		
Justicia sp.		Ngetkitom.		
Leucas microphylla		Kapsaina.		
Phyllanthus guineensis		Kariablakwa.		
Rhus natalensis		Siriandet.	Modeve. Kitheu. Musakasaka.	Ol Mesigie.
Sida schimperiana		Korkoriet.		
Solanum incanum	Mtula. Mtungujamito.	Labotvet.		
Tarchonanthus camphoratus	Mkalambati.	Leleshwa.		Ol Leleshwa.
Terminalia brownei	Mbambaro.	Koloswet.	Mumku. Muhuku.	
Trianthema pentandra		Tuigatiet.		
Withania somnifera		Kibarariet.		Ol Asajet.
Ziziphus mucronata	Mkunazi.	Noiuwet.	Muayi.	Ol Oilale.

TABLE I.—THE CHEMICAL COMPOSITION OF BROWSE PLANTS OF KENYA
(Per Cent of Dry Matter)

BOTANICAL NAME	DESCRIPTION	Source	Date	Ash	Crude Protein	Ether Extract	Crude Fibre	Carbo-hydrate	Ca	P
SECTION 1										
Acacia brevispica	Early fruiting stage, leaves	S. Baringo	Aug. 1956	6·54	18·79	5·67	17·99	51·01	1·86	0·31
Acacia brevispica	Early fruiting stage, young pods	,,	Aug. 1956	4·61	17·50	1·08	24·02	52·79	0·46	0·27
Acacia gerrardii	Young twigs and leaves	,,	Feb. 1957	6·01	17·72	1·60	24·19	50·48	0·63	0·25
Acacia mellifera	Very young leaves	,,	Feb. 1957	6·17	42·85	2·60	16·19	32·19	0·51	0·58
Acacia seyal	Bark of branches	,,	Aug. 1956	6·59	4·34	0·71	20·68	67·68	4·09	0·03
Acacia seyal	Bark of branches	,,	Feb. 1957	8·81	10·59	0·91	22·15	57·54	2·50	0·07
Acacia tortilis subsp. *spirocarpa*	Pods with beans	,,	Jan. 1957	8·37	17·79	1·74	17·50	54·60	1·34	0·36
Acacia nilotica subsp. *subalata*	Pods with beans	,,	Feb. 1957	6·55	10·44	0·82	19·76	62·43	0·53	0·16
Acacia nilotica subsp. *subalata*	Top branches and leaves, some flowers	,,	Feb. 1957	5·47	11·92	2·18	21·35	59·08	0·87	0·13
Acacia nubica	Leaves	,,	Nov. 1957	8·85	32·45	1·73	15·76	41·21	1·71	0·44
Acacia nubica	Pods	,,	Nov. 1957	7·46	15·17	1·91	37·42	38·04	1·46	0·23
Achyranthes aspera	Twigs, with leaves	,,	Feb. 1957	18·65	26·43	1·45	20·19	33·28	1·79	0·31
Albizia amara	Young branches and leaves	,,	Feb. 1957	6·14	26·78	1·93	26·80	38·35	0·47	0·25
Albizia amara	Flowers	,,	Feb. 1957	7·02	26·85	1·73	21·44	42·96	1·02	0·28
Balanites aegyptiaca	Young branches and leaves	,,	Feb. 1957	6·57	27·48	1·46	23·28	41·21	0·48	0·38
Boscia angustifolia	Young branches and leaves	,,	Feb. 1957	7·10	19·29	1·33	39·25	33·03	0·61	0·18
Cadaba farinosa	Young branches with leaves and some pods	,,	Aug. 1956	7·04	18·15	1·81	27·31	45·69	0·39	0·17
Capparis elaeagnoides	Young twigs and leaves	,,	Feb. 1957	9·19	25·77	2·30	21·49	41·25	0·62	0·19
Celosia anthelmintica	The whole plant, in full bloom	,,	Aug. 1956	6·54	14·98	2·07	32·90	43·51	0·56	0·18
Croton dichogamus	Young shoots with leaves	,,	Feb. 1957	10·48	25·14	2·00	20·08	42·30	1·86	0·49
Fagara chalybea	Leaves	,,	Aug. 1956	6·77	10·28	3·29	19·29	60·37	1·70	0·47
Grewia bicolor	Young branches with leaves	,,	Aug. 1956	6·05	12·73	3·50	22·99	54·73	1·60	0·30
Grewia kakothamnos	Young branches with leaves	,,	Aug. 1956	7·70	8·69	2·53	32·56	48·52	1·53	0·38
Hibiscus lunariifolius	Young twigs and leaves	,,	Feb. 1957	9·19	17·76	1·56	37·35	34·14	1·93	0·33
Justicia exigua	The whole plant at the flowering stage	,,	Aug. 1956	18·86	14·04	3·25	21·92	41·93	1·67	0·45
Justicia sp.	Terminal branches and leaves; some ripe pods.	,,	Feb. 1957	6·87	15·26	2·52	34·10	41·25	0·65	0·18
Leucas microphylla	Flowering stage	,,	Aug. 1956	8·75	11·35	3·26	34·09	42·55	0·91	0·62
Phyllanthus guineensis	Young branches with leaves, flowers and young fruits.	,,	Aug. 1956	4·63	5·32	1·75	49·01	39·29	0·72	0·31
Rhus natalensis	Young branches with leaves	,,	Aug. 1956	5·15	10·15	1·93	23·09	59·68	0·59	0·21
Rhus natalensis	Young twigs with leaves	,,	Feb. 1957	8·79	9·04	3·53	19·65	58·99	1·43	0·10
Rhus natalensis	Young to almost ripe fruits	,,	Feb. 1957	4·03	11·06	5·82	25·29	53·80	0·27	0·19
Sida schimperiana	Branches and leaves	,,	Feb. 1957	11·32	13·67	1·30	29·90	43·81	1·00	0·24
Solanum incanum	Leaves	,,	Feb. 1957	12·75	30·28	2·01	21·00	33·96	1·56	0·32
Tarchonanthus camphoratus	Tips of branches and leaves	,,	Feb. 1957	5·81	11·36	6·71	26·79	49·33	0·37	0·10
Terminalia brownei	Young branches with leaves	,,	Aug. 1956	6·12	5·73	3·62	16·19	69·34	1·24	0·11
Terminalia brownei	Young branches with leaves and young pods.	,,	Aug. 1956	5·62	10·29	2·90	16·66	64·53	0·82	0·13
Trianthema pentandra	Herbage at the late flowering stage	,,	Aug. 1956	17·92	16·47	2·52	23·10	39·99	1·04	0·27
Withania somnifera	Twigs with leaves	,,	Feb. 1957	20·02	29·87	2·11	13·98	34·02	1·93	0·43
Ziziphus mucronata	Young branches and leaves	,,	Feb. 1957	9·41	14·28	2·56	8·43	65·32	4·68	0·17

TABLE I.—THE CHEMICAL COMPOSITION OF BROWSE PLANTS OF KENYA—(*Contd.*)

(Per Cent of Dry Matter)

BOTANICAL NAME	DESCRIPTION	Source	Date	Ash	Crude Protein	Ether Extract	Crude Fibre	Carbo-hydrate	Ca	P
SECTION 2										
Acacia sieberiana	Pods	Kipkarren	Oct. 1955	4·02	11·62	1·43	40·24	42·69	0·10	0·14
Acalypha wilkesiana	Leaves	Kitale	Sept. 1955	12·33	15·96	3·97	11·95	55·79	2·03	0·72
Achillea millefolium (yarrow) ..	Young leaves	,,	Oct. 1955	15·25	19·28	1·90	14·71	48·86	1·05	0·32
Carum carvi (Caraway) ..	Young leaves	,,	Oct. 1955	15·81	13·47	1·95	13·31	55·46	0·92	0·43
Cichorium intybus (Chicory) ..	Young leaves	,,	Oct. 1955	15·87	13·81	2·88	13·85	53·59	1·56	0·23
Cichorium intybus	Leaves	,,	Jan. 1957	15·22	15·35	5·28	15·01	49·14	1·67	0·20
Diplolophium africanum ..	Tassels, pre-flowering stage of growth ..	Cherangani	May 1954	14·29	22·44	5·00	13·68	44·59	3·02	0·46
Diplolophium africanum ..	Tassels, after flowering	Lumbwa	Oct. 1955	9·89	10·76	4·45	16·92	57·98	2·10	0·17
Diplolophium africanum ..	Very young plant, 12 in. tall	Kitale	Oct. 1955	13·85	17·71	2·81	13·68	51·95	1·11	0·45
Heeria reticulata	Leaves	,,	Nov. 1956	5·17	9·01	10·52	20·86	54·44	1·29	0·07
Hypericum lanceolatum ..	Leaves	Eldoret	May 1956	4·33	15·31	7·01	14·53	58·82	0·53	0·27
Inula decipiens	Leaves (24·04% SiO_2)	Kipkarren	Oct. 1955	34·99	7·84	2·45	28·69	26·03	1·52	0·25
Portulacaria afra	Whole plant, 1 ft. tall	Kitale	May 1956	19·13	10·67	3·81	11·86	54·53	1·40	0·12
Plantago lanceolata (Plantain)	Young leaves	,,	Oct. 1955	12·90	15·93	2·18	13·34	55·65	1·54	0·29
Plantago lanceolata	Leaves	,,	Jan. 1957	10·72	12·21	2·66	11·43	62·98	1·53	0·21
Poterium polygamum (Burnet)	Young leaves	,,	Oct. 1955	10·10	18·88	3·37	11·88	55·77	0·99	0·31
Poterium polygamum	Leaves	,,	Jan. 1957	7·20	12·53	5·38	11·57	63·32	1·18	0·26
Sesbania sesban	Leaves	Kipkarren	Oct. 1955	7·57	25·97	2·64	14·39	49·43	1·11	0·27

Acacia sieberiana DC. (Leguminosae)

A large tree which occurs in Kenya at medium altitudes, from 4,000 to 7,000 ft. It has large thick fleshy pods which become hard at maturity. The pods are said to be liked by rhinoceros and elephants.

Inula decipiens E.A. Bruce (Compositae)

A tall perennial herb with very large, hairy basal leaves. It occurs in *Combretum* woodland and at forest edges at altitudes from 6,000 to 8,000 ft., mainly west of the Rift Valley. It is a good source of calcium, but the silica content of its leaves is outstandingly high.

Sesbania sesban (L.) Merrill (Leguminosae)

A shrub or a small tree with large pinnate leaves and yellow flowers. It is common in Kenya under a wide range of altitudes, and it is to be found growing either on stream banks or at swamp edges. The leaves are a very good source of protein and of calcium and they are not fibrous.

Acalypha wilkesiana (Muell) Arg. (Euphorbiaceae)

A native of Melanesia, called "copper leaf" and widely cultivated in gardens as an ornamental shrub (Greenway, 1955). The leaves contain high proportions of crude protein, calcium and phosphorus.

Diplolophium africanum Benth & Hook. (Umbelliferae)

A tall biennial or perennial herb with large leaves divided into numerous linear lobes. It is common in western Kenya at altitudes of 6,000 to 8,000 ft. where it occurs in bush, at forest edges and by roadsides. The tassel-like leaves, as analysed, were reported to be liked by cattle, though doubt as to the palatabiilty of this herb has been expressed in some quarters.

Five cultivated European herbs (burnet, chicory, caraway, plantain and yarrow) have been grown at the Grassland Station from exotic seed; plantain and chicory appear to be the most vigorous, and the latter better able to withstand dry conditions. Chemical analysis shows that these herbs are a very useful source of protein, calcium and phosphorus and that they are not fibrous.

ACKNOWLEDGMENTS

We wish to thank Mr. R. N. Edmondson and his African staff for their assistance in the collection of browse plants from the South Baringo District, for their valuable information on the usefulness of these plants as fodder, and for their Tugen names. Our thanks also are due to the staff of the Royal Botanic Gardens, Kew, and to Dr. P. J. Greenway and Dr. B. Berdcourt, of the East African Herbarium, Nairobi, for identifying some of our specimens and for supplying tribal names of the plants.

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REVIEW

YEASTS, edited by W. Roman, published by Dr. W. Junk, 13, Van Stolkweg, The Hague, Netherlands, 1957, pp. 246, price 25 guilders or $7.00 U.S.

Several authors have contributed to this comprehensive review of yeasts; K. Arima, W. J. Nickerson, M. Pyke, H. Schanderl, A. S. Schultz, A. C. Thaysen and R. S. W. Thorne. One section deals with baker's yeast, another with brewer's yeast, a third with wine and fruit yeast, a fourth with sake and similar yeasts used in the Far East, a fifth with food and fodder yeasts, and a sixth with the medicinal and nutritional aspects of yeast preparations. In each section the cultivation and industrial production, and the biology and chemistry of the particular group of yeasts are discussed in detail, and numerous references to original literature are included. It seems that no work has been published on the yeasts which are active in the preparation of rum from molasses, since no references to these appear in the book.

D.W.D.

THE LIMITED UTILITY OF FLOOD-WATER IN THE PERKERRA RIVER IRRIGATION SCHEME, KENYA

By H. C. Pereira, East African Agriculture and Forestry Research Organization, in co-operation with the Hydraulic Branch, Ministry of Works, Kenya

(*Received for publication on 15th July, 1957*)

Introduction

Initial developments of irrigation from the Perkerra River at Marigat were carried out by the African Land Development Board and the Agricultural Department staff, using Kikuyu prison labour without engineering assistance. These trial plots produced fair yields of maize, sorghum, groundnuts and sugar-cane in 1954, and thus supplied much useful food for the maintenance of the large prison camp. They thereby showed the soil to be fertile with no immediate salinity problems. Water distribution was found to be a major difficulty requiring accurate levelling in the setting out of land. The Hydraulic Branch of the Ministry of Works undertook the designing of the canal system for the full 4,000-acre scheme. In addition, the problem of devising an efficient system of water distribution within the fields was passed to the Hydraulic Branch, who invited the co-operation of the Physics Department of E.A.A.F.R.O. in the necessary investigation work. This paper reports results of the first study, which was to find whether heavy waterings could be distributed to make the maximum use of high flood flows, and describes the experiments in progress in the second study, which is of methods for economising in water by matching irrigation to measured water use by the crops.

Irrigation by Single Heavy Flooding

As yet, little is known of the variability of the Perkerra River. Fig. I summarizes the information obtained from two and a half years gauging in the years 1935-1937, and the three years subsequent gauging, which began in 1953 and is continuing.

There is a suggestion of a deterioration in the regime of the river, and the present overgrazed and eroded condition of a great deal of its catchment area supports the suggestion that infiltration has deteriorated severely in the past 20 years. Comparison with the long-term records of the Molo River, whose catchment area topography and geology are similar, show that the flash-flood regime indicated by the present brief records is characteristic. Peak floods have been observed to reach 55,000 cusecs on the Perkerra, and low flows of 10 cusecs. or less may be expected for two or more months annually. The 80-cusec capacity of the intake canal is designed to permit use of high river flows. The very low dry-weather flow of the Perkerra River in the present state of its catchment offers no prospect of full perennial irrigation of the 4,000 acres commanded by the main canals for the present scheme. Mr. F. A. Brown, Irrigation Adviser to the Kenya Department of Agriculture, in his 1954 "Review of the Perkerra River Scheme" suggested that the peak floods should be utilized to the full extent of the 80-cusec intake canal in order to supply a single heavy flooding to basins over a wide area; the crop would be grown on the stored soil moisture from this single flooding. This possibility would considerably affect the development of the whole scheme, and has been given priority in the studies reported here.

Soil Physical Characteristics

Land having the most favourable soil type is at present being cleared from an indigenous open forest of tall acacia (*Acacia spirocarpa*). These trees, which reached diameters of 20 in. or more, have a short-grass cover between them, and their size indicates successful use of stored flood water. This soil is of very uniform, deep, friable silt, with unusually good structure throughout the first 6 ft. sampled. No horizons of impeded drainage were discovered, and the soil texture, although somewhat variable, lies within the ranges 30–40 per cent fine sand, 50–80 per cent silt, 2–11 per cent clay. Undisturbed soil cores taken from pits showed adequate laboratory percolation rates throughout the 6 ft. sampled, and tension plate tests gave the results shown in Table I.

Table I shows an adequate storage capacity for soil moisture for irrigation purposes, and some 16 in. of water can theoretically be applied to the first 6 ft. in its fully dry condition after a crop has been removed and the surface baked by the sun.

Flood-watering in Flat Basins

Four ¼-acre plots were surrounded by bunds, and by a 6-foot outer bunded guard-ring. The first two were given initial floodings of 20 in. in one application which is the amount calculated to bring the first 6 ft. of soil to the one-third of an atmosphere field capacity, plus an allowance for evaporation losses during application. Rainfall immediately preceding the flooding was counted in this total. The flooding of these first two basins was given at three-week intervals in order to vary the weather experienced during the subsequent crop growth. Two further basins, each of ¼ acre, were given 30 in. and 40 in. respectively, representing approximately 50 per cent and 100 per cent increases on the theoretical amount, to investigate the extent to which extra heavy applications of the water available during the peak flow of the river might assist in subsequent cropping. Infiltration was completed in 24 hours on the two basins receiving 20 in. each, and in 48 hours on the basins receiving the heavier waterings. In all cases the basins were sampled for soil moisture in the first 6 ft. before flooding, and at frequent intervals throughout the life of the subsequent maize crops in order to follow the distribution of water in the soil and its use by the crop. Using the data from the core samples already taken, the moisture results were converted to inches of water. Table II summarises the results which are plotted in Fig. II.

Basin A

After application of 20 in. of water, the water content of the first 6 ft. of the soil was raised from 12 to 23 in. approximately, showing a loss of some 9 in. of the applied water. Data from a nearby evaporation pan showed that less than 1 in. of this could be ascribed to evaporation losses, and that 8 in. had been lost by downward percolation beyond 6 ft. Evaporation and crop transpiration then steadily reduced the available water in the first 3 ft. of the soil throughout the first 80 days after planting. Rainfall was largely in slight and ineffective showers, and over the life of the crop added about 1 in. to the effective stored water supply. The water distribution in the subsoil from 3 ft. to 6 ft. was highly variable for more than a month, and thereafter, although becoming more uniform, showed no loss during the life of the crop. Samples taken within a circle of 10-ft. radius in the centre of the field, compared with others taken at random over the ¼-acre basin gave very good agreement.

Table I—Soil Water Storage Capacity in the First Six Feet

(Inches depth of water)

Soil Depth	"Field Capacity"		Wilting Point *(1 in. lost by sun-drying of surface)	Field Storage Capacity for available water
	Laboratory conditions Soil Cores at 1/3 atm.	Field Conditions 4 days after flooding		
0–3 ft.	13·0	13·3	4·6*	7·7*
3–6 ft.	15·1	13·4	4·8	8·6
0–6 ft.	28·1	26·7	9·4	16·3

Table II—Flooding of Levelled Basins

(Soil Water Storage, in inches, as achieved by different flooding treatments)

Basin	Initial Moisture Contents	Inches of Water Applied	Inches of Water Found after Irrigiat,on					
			Two to four days after flooding			Ten days after flooding		
			0–3 ft.	3–6 ft.	0–6 ft.	0–3 ft.	3–6 ft.	0–6 ft.
A	12·3	20	12·3	11·0	23·3	10·2	10·0	20·2
B	9·4	20	13·5	12·4	25·9	10·0	12·0	22·0
C	14·1	42	12·3	12·7	25·0	10·2	10·5	20·7
D	10·7	30	13·3	13·4	26·7	12·1	12·0	24·1

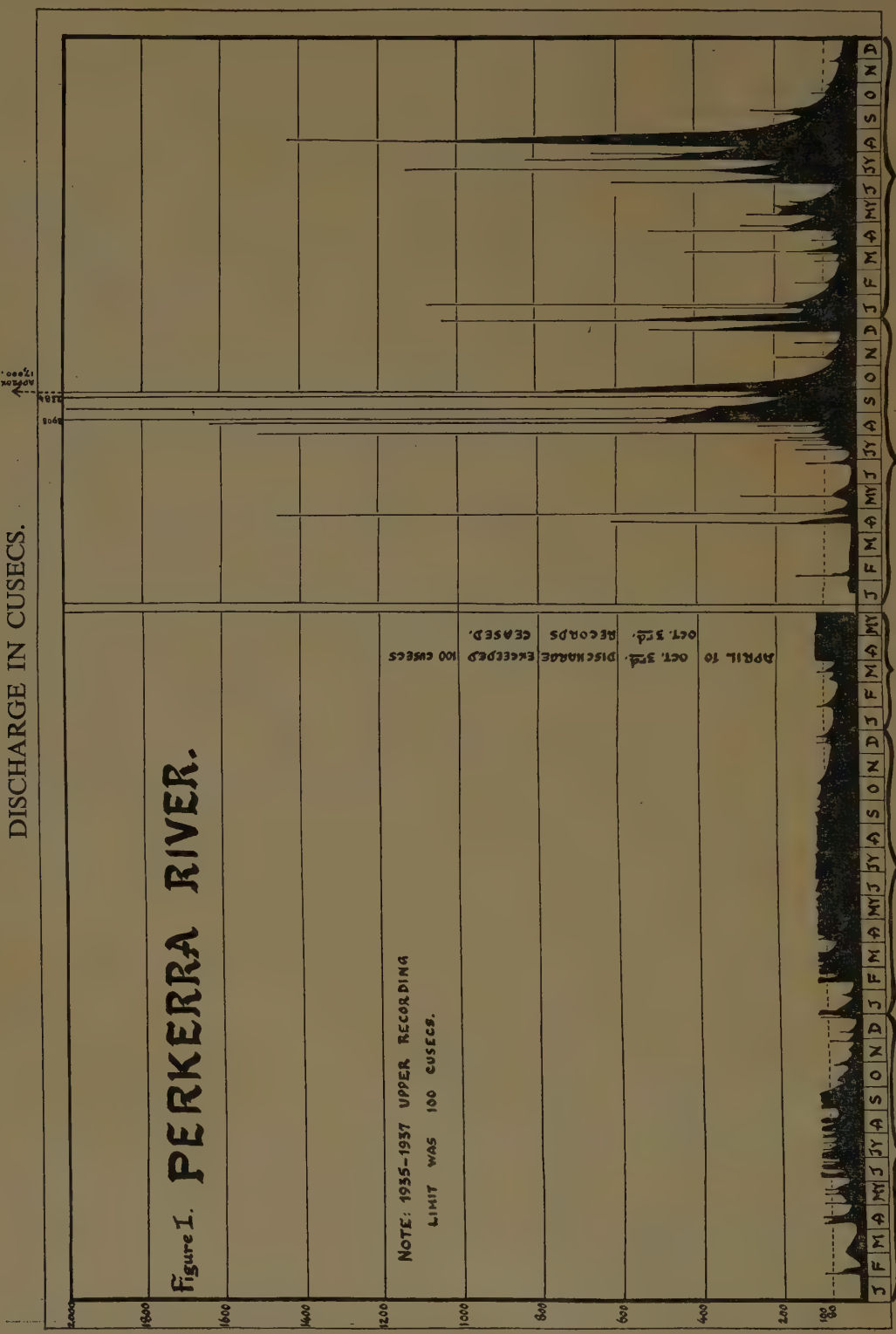
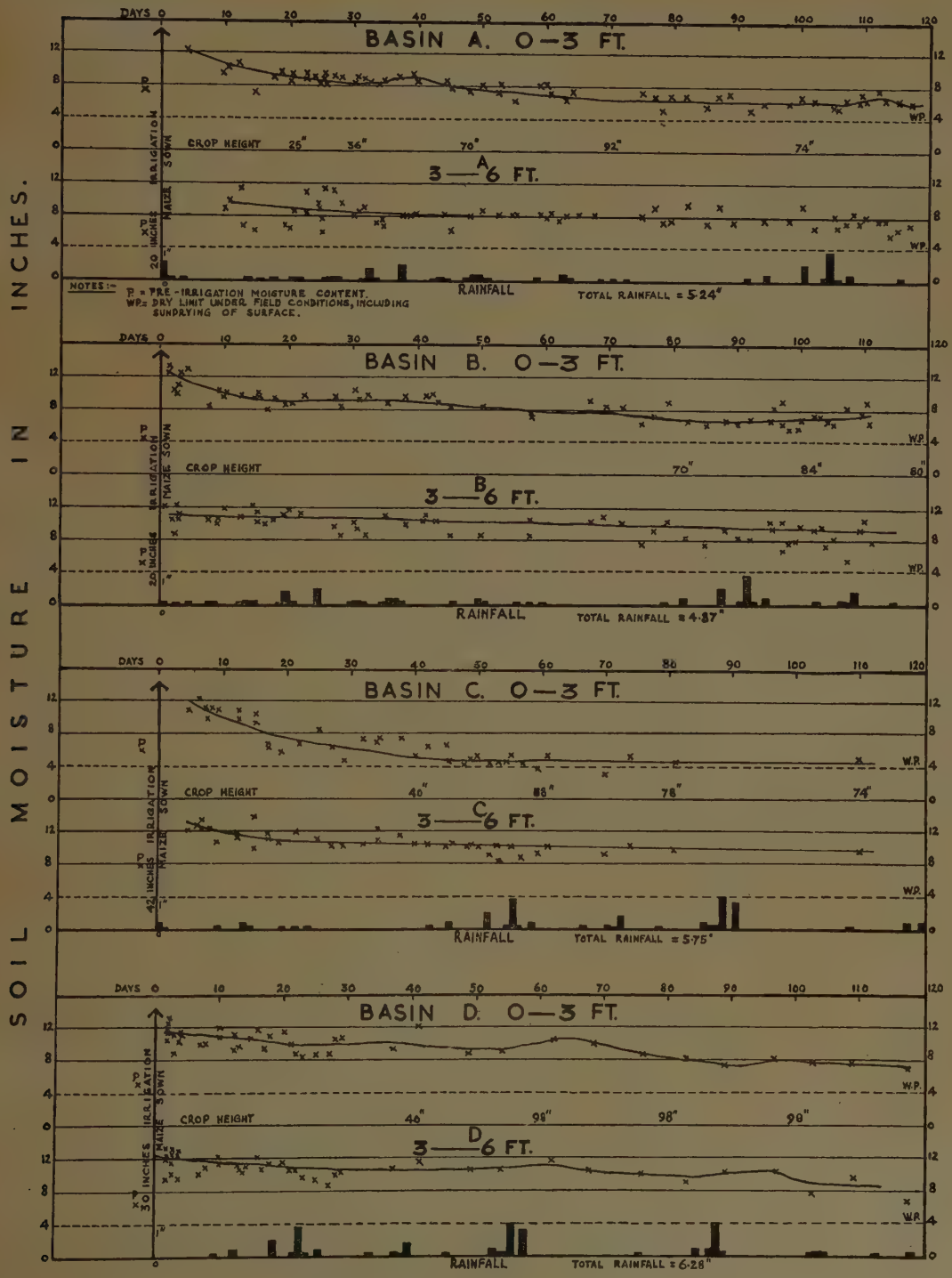

DISCHARGE IN CUSECS.
Figure I. PERKERRA RIVER.
NOTE: 1935-1937 UPPER RECORDING LIMIT WAS 100 CUSECS.
APRIL TO OCT. 3rd. 100 CUSECS
DISCHARGE RECORDS CEASED. KEEPER
OCT. 3rd.
2000
1800
1600
1400
1200
1000
800
600
400
200
100
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1935
1936
1937
1955
1956

Fig II. SOIL MOISTURE IN FLOODED BASINS, PERKERRA IRRIGATION SCHEME.



The average height of a sample of five plants is shown in Figure II. Sporadic wilting was observed 70 days after planting, and growth stopped. Maize began to cob, but wilted before a crop could mature. At 90 days the whole crop dried out and the yield was less than 100 lb. per acre.

Both the soil moisture sampling and observations of roots showed that all rooting had been confined to the first 2 ft. of soil, which at the time of crop failure was reduced below wilting point. While the plants were dying of drought, there remained from 3 in. to 4 in. of available water in the immediate subsoil between the 2-ft. and 6-ft. depths.

Basin B

Flooded and planted three weeks later, this basin gave a very similar result. The subsoil proved to be more freely draining, so that moisture content from 3 ft. to 6 ft. was somewhat less variable than in Basin A, but showed a steady decrease as water was lost by drainage. The crop died at about the same stage and for the same reasons.

Basins C and D

The extra heavy floodings produced higher initial drainage losses, and much more rapid subsequent drainage losses from both upper and lower subsoil depths, but, as can be seen from Figure II, individual samplings still showed dry spots in the flooded basins below 2 ft., illustrating that even the heavy flooding could not overcome the uneven penetration of water in this newly cleared soil. The crops failed in both cases at the same stage with even more restricted root ranges and even more water left unused in the subsoil. It will be seen that in the case of Basin D some 3 in. of effective rainfall occurred during the growth of the crop, and although this penetrated below 3 ft. it failed to save the yields.

These results show clearly that the air supply in the subsoil after flooding is inadequate to permit normal root penetration.

Growing of crops on the single-flood application of water has been outstandingly successful in a few places such as the Gash Delta in the Sudan, where the soils are not only deep but are extremely well drained and aerated. In the heavy silty soils of the Perkerra Scheme flooding merely results in the restriction of roots to the better aerated surface horizons. During the earlier stages of crop development, the maize roots grow deeper as the upper soil dries out, but when cobbing begins starch supplies of the maize are diverted to the formation of seed, and and the roots fail to extend to the deeper soil in which water is available.

THE RIDGE AND FURROW METHOD OF IRRIGATION

This system was needed to distribute water over land of too great a slope for economic reduction to flat basins or terraces. A comprehensive series of furrow-length and furrow-gradient combinations were first constructed to ascertain the combination of length and gradient which would achieve an even distribution of water within a single furrow. The best results were obtained for 500-ft. length of furrow at gradients at between 1/750 and 1/1,000. With the drop in infiltration rate which is to be expected when newly cleared land comes under arable use, the most suitable gradient will lie between 1/1,000 and 1/1,250. It was found that, in order to obtain an adequate wetted area for infiltration, furrows were necessary at 3-ft. intervals, the maize being planted on each ridge. Sets of three parallel furrows were then prepared to 1/1,000 gradients with the assistance of a precision level under close European supervision. When pegs were levelled at 40-ft. intervals, in spite of careful construction water was found to concentrate in the middle of the 500-ft. furrows, and subsequent crops were poor at the extremes. It was found necessary to level pegs at 20-ft. intervals in order to obtain reasonably good water distribution. Effects of uneven distribution in the earlier sets of furrows were very strikingly reflected in the height of the subsequent maize crops.

With this somewhat elaborate preparation, three sets of furrows were constructed 500 ft. long at a slope of 1/1,000 and three or more replicate profiles of soil moisture samples to 6 ft. were obtained near the beginning, middle and end of each set of furrows, to establish the initial conditions of water storage.

From the basin experiments it was clear that periodic watering would be essential. The use of as heavy as possible an initial application in order to make maximum use of the transient flood supplies is dictated by the unfavourable regime of the river. An initial heavy watering was therefore further investigated in the ridge-and-furrow method of application.

Table III—Heavy Initial Applications of Water by Ridge and Furrow

Sets of three furrows, 500 feet long, at 1/1,000 slope. Inches of water per three feet of soil (Means of three to six replicate profiles)

Sampling Areas	0–100 ft.	200–300 ft.	400–500 ft.	
		Set 23		
		Before Irrigation		
0–3 ft.	5·3	5·4	4·7	
3–6 ft.	4·7	5·6	5·6	
Total 6 ft.	10·0	11·0	10·3	21 inches applied.
		One Week after Completion of Irrigation		
0–3 ft.	8·8	11·7	12·1	
3–6 ft.	5·6	9·1	10·0	
Total 6 ft.	14·4	20·8	22·1	
		Increase in Available Soil Moisture Storage		
0–3 ft.	3·5	6·3	7·4	
3–6 ft.	0·9	3·5	4·4	
Total 6 ft.	4·4	9·8	11·8	Average increase 8·7.
		Set 24		
		Before Irrigation		
0–3 ft.	5·5	4·5	4·3	
3–6 ft.	5·1	4·5	4·8	
Total 6 ft.	10·6	9·0	9·1	16 inches applied.
		One Week after Completion of Irrigation		
0–3 ft.	10·1	11·2	10·5	
3–6 ft.	6·5	6·2	6·3	
Total 6 ft.	16·6	17·4	16·8	
		Increase in Available Soil Moisture Storage		
0–3 ft.	4·6	6·7	6·2	
3–6 ft.	1·4	1·7	1·5	
Total 6 ft.	6·0	8·4	7·7	Average increase 7·4.
		Set 25		
		Before Irrigation		
0–3 ft.	4·6	4·6	4·2	
3–6 ft.	4·8	4·8	4·6	
Total 6 ft.	9·4	9·4	8·8	16 inches applied.
		One Week after Completion of Irrigation		
0–3 ft.	11·2	10·4	10·0	
3–6 ft.	11·2	8·8	10·2	
Total 6 ft.	22·4	19·2	20·2	
		Increase in Available Soil Moisture Storage		
0–3 ft.	6·5	5·8	5·8	
3–6 ft.	6·4	4·0	5·6	
Total 6 ft.	12·9	9·8	11·4	Average increase 11·4.

One set of furrows (No. 23) was given a total initial watering of 21 in. Intensive soil sampling to 6 ft. was then carried out and was continued at intervals throughout the life of the crop. Table III shows the increments of stored available soil moisture resulting from this irrigation and from that of two subsequent sets of furrows. The increase in water storage was disappointing, only 4 in. being added in the first 100 ft. of furrow, 10 in. in mid-furrow, and 12 in. in the last 100 ft. Using data from the evaporation tank nearby, evaporation losses were estimated at about 6 in., since an interruption of water supplies caused the initial waterings to be spread over three weeks. With an average storage increment of only 8.7 in. this means that over 6 in. of water penetrated beyond the 6-ft. depth, i.e., beyond the root range to be expected from maize in these soils.

The downward loss of water was excessive, and in the next trial (No. 24) initial watering was reduced to 16 in., and the application was made more intensive. This resulted in a greater uniformity of distribution, but the average increment to useful water storage was now only 7 in.

The same application was repeated with a third set of furrows (No. 25), but with deeper and very thorough preliminary cultivation. This resulted in a substantially greater increase in useful water storage, the average increment now being 11.4 in.

From these results it is concluded that in such heavy silts the ridge-and-furrow method of watering cannot usefully distribute an initial application exceeding 12 in. Since this would not bring crops to maturity without subsequent irrigation the use to which peak riverflows can be put must remain limited to the areas which could be maintained from the low dry-season flow.

Irregularity of Water Penetration

Subsequently, two adjacent 15-acre areas were laid out for larger scale comparison of the preparation of basins and of ridges and furrows. This work emphasized the importance of some preliminary land smoothing, without reduction of slope, in the preparation of ridge-and-furrow systems if these are to be simple enough for peasant cultivation. Sets of four small fields under each type of distribution were equipped with tensiometers and electrical resistance moisture gauges (cylindrical gypsum blocks) for a study of the soil moisture regime under a routine watering economy. Both systems showed wide variations in water penetration into the first 2 ft. of soil under the first three successive crops on this newly cleared land.

Field Work

Some details of the field work may be of practical interest. Using prison labour and an improvised field laboratory with an oil-fired oven, the field staff of the Hydraulic Branch carried out well over 2,000 soil moisture determinations in these studies. Some 300 duplicate samples were weighed in the field and dispatched to E.A.A.F.R.O. for oven-drying at Muguga to maintain a check on the field determinations. Attempts to sun-dry soil samples in lieu of oven-drying were found to be ineffective and were discarded. Consistent and useful information was eventually obtained from over 1,500 samples. The data were processed and analysed by E.A.A.F.R.O.

Conclusions

The storage in the soil of surplus water from the high-flood supplies of the Perkerra River is strictly limited, and neither basin nor furrow method of initial distribution can eliminate the need for further substantial waterings. The quantities necessary, and the optimum intervals, are still under investigation, but it is clear that heavy reliance must be placed on the use of the slender dry-weather river flow. If two crops per year are to succeed on 4,000 acres, substantial improvements in the dry-weather flow must be secured by better management of the Perkerra River catchment area. Destructive over-grazing must be controlled and the vegetation permitted to recover until rainfall infiltration rates are restored. At the same time methods must be devised to secure substantial economy of water use in the dry seasons, since this factor will determine the proportion of the land now commanded which can be put to productive use. Such economy can best be achieved by relating irrigation rates to progressive crop requirements within each season.

Subsequent Experiments

A most promising device for the routine assessment of evaporation losses is the simple distillation-type radiation integrator. This was developed by Gunn, Kirk and Waterhouse (*J. exp. Biol. 22*, 1-7, 1945) from the original

invention of Bellani. It is both cheaper to install and simpler to operate under tropical conditions, than an open-water evaporation tank. Experiments now in progress are comparing routine watering at 4 in. every 15 days, as used on the rest of the Scheme, with watering to meet the losses indicated by the radiation integrator (now known commercially as a "B.T.L. Radiometer"). The control treatment is the maintenance of soil moisture at optimum levels as indicated by both tensiometers and gypsum blocks. The water applied is recorded autographically.

Summary

The Perkerra River has a violently flash-flooding regime varying from 55,000 to 10 cusecs. The canal system commands some 4,000 acres of rich deep silt-loam. Experiments on the use of a single heavy flooding for the growth of crops on stored soil moisture are described. Both basin flooding and ridge-and-furrow irrigation succeeded in charging the first 6 ft. of soil with between 10 and 12 in. of stored available water. Maize roots failed to penetrate more than 2 ft. into the heavy wet soil, and the crops died without using the water stored between the 2-ft. and 6-ft. depths.

These results show that the success of this Irrigation Scheme must depend on the maximum economy and efficiency of water use. Yield responses are now being measured for waterings assessed both by tensionmeters and gypsum blocks, and by the use of a simple distillation-type radiation integrator.

The paramount urgency of improvement of land-usage throughout the catchment area is stressed.

Acknowledgments

These experiments were initiated by Mr. B. R. Koch, Deputy Hydraulic Engineer, whose continued advice and help have been most essential to their progress. Credit is due to Messrs. M. J. Wessels, G. D. M. Campbell and I. Gordon of the M.O.W. Hydrology Section, who carried out the field work, and to Mr. P. H. Hosegood of E.A.A.F.R.O. who carried out the laboratory work. Thanks are also recorded to the staff of the Agricultural Department for their co-operation.

REVIEW

Insect Life in the Tropics, by T. W. Kirkpatrick, published by Longmans, Green & Co., London, 1957, XIV + 311 pp., 146 figs., price 35*s*.

Professor Kirkpatrick who as an entomologist has spent over 30 years in Africa and the British West Indies is well qualified to write this introduction to tropical insects. His book is intended not for the specialist but anyone who is interested to know more of the creatures crawling on and around him. The initial chapters contain enough about the structure and classification of insects to render the rest of the book intelligible to anyone, and those with little or no previous knowledge of entomology will find this part useful as an elementary text-book. Development from egg through the larval or nymphal stages to the adult is discussed and this is followed by the numerous and sometimes gruesome aspects of insect reproduction. In their food and feeding habits insects show greater diversity than any other group of animals and all aspects are mentioned including cannabilism which is prevalent in some species. All forms of locomotion (including a form of jet-propulsion) are used by insects and there are many methods of defence such as camouflage and mimicry. Nest building and insect architecture in general, together with the social life of bees, termites and many less well-known insects form a fascinating study to which the reader is introduced. Many good quality photographs and excellent line drawings add to the interest of this well produced book which is worthy of the attention of all naturalists.

I.W.B.N.

GAME ELIMINATION AS A TSETSE CONTROL MEASURE IN UGANDA

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Early travellers in Uganda described the country as relatively free of tsetse flies, but the exact situation remained unknown for many years. Throughout most of the country there appears to have been an unstable balance between, on the one hand, the savannah tsetses, *G. morsitans* and *G. pallidipes*, and the game animals, and on the other the pastoralists and their cattle. Contributing largely to the instability of this balance were periodic outbreaks of rinderpest. Such outbreaks could, and apparently did, sway the balance in different directions at different places and different times. In some instances the reduction in game density by this disease resulted in the disappearance of fly from areas of relatively unsuitable bush. In others the fly retained the upper hand because game returned more quickly than did the cattle-owners to the areas affected by the rinderpest.

In the course of the 1920's two new factors came into operation in central Uganda. The first of these was restriction of age-long elephant movements, and reduction in elephant numbers, in Bunyoro and N. Mengo, by development of road communications and exploitation for ivory. The second was the institution, as part of agricultural policy to prevent erosion, of early grass-burning. Both of these developments served to encourage a natural tendency towards progressive densification of bush in these areas. This process caused much of the formerly open fly-free grazing country to become potential tsetse country, so that when the next wave of tsetse extensions occurred in the late 1930's and early 1940's nearly 8,000 square miles of cattle country in northern and central Uganda were lost to *G. morsitans* and *G. pallidipes* in the course of a very few years.

The Major Tsetse Advances in Central and North-Central Uganda

The accompanying map has been prepared to illustrate only those areas covered by advances of *G. morsitans* and/or *G. pallidipes* which took place in central and north-central Uganda from about 1935 onwards, and which have subsequently been reclaimed almost entirely (or are still in the process of reclamation) by game elimination. The total extent of such areas is approximately 6,300 square miles.

On the map are shown also the directions of the various advances by the two species, *G. morsitans* and *G. pallidipes*. By districts, the areas denied to cattle by the advances with which this paper is concerned were:—

(*a*) About 1,800 square miles of Acholi District, covered by an invasion of *G. morsitans* starting from the north and rapidly spreading southward and eastwards (and linking up eventually in the east with a concurrent *morsitans* invasion of Karamoja*).

(*b*) About 3,000 square miles in north Mengo District of Buganda, covered by advances of *G. pallidipes* and *G. morsitans* from various directions as shown by the arrows, together with 800- and 700-square mile stretches in the adjoining parts of S.E. Bunyoro and S.W. Lango Districts respectively.

If, by the early 1940's, these advances had come up against barriers of population or naturally unfavourable country the position would have been serious enough. But this was by no means the case. By 1944 the southern advances in Mengo District had arrived within 35 miles of Kampala, and the invasions in Acholi and Karamoja had crossed the northern borders of the Lango and Teso Districts which are the two most important cattle-producing districts in the Protectorate: all the advances were, moreover, still making rapid progress at that time, and there seemed to be nothing to stop them from proceeding very much further. So grave was the position that the very existence of the cattle industry in the Protectorate was threatened.

* The 1,700 square miles of country denied to cattle by this *G. morsitans* invasion of Karamoja were also reclaimed between 1947 and 1952, but not by hunting. The Karamoja country differs in being predominantly short-grassed *Combretum* woodland, and the discontinuous distribution of fly made it more economic to reclaim by selective bush-clearing.

Nor were these threats to cattle the whole story. In 1940–42 there had been a serious outbreak of Rhodesian sleeping sickness in south Busoga, which was shown to have been carried by *G. pallidipes*. By 1946 this tsetse had spread from south Busoga into Bugerere County, Mengo, and in consequence there appeared to be very real risk of further spread of this type of human trypanosomiasis throughout the Protectorate.

The Country

The country in the areas reclaimed by game elimination is for the most part flat, or gently undulating, long-grassed, mixed *Combretum* woodland. The valleys in most of the country are broad seasonal grass swamps, sometimes fringed by stands of tall *Acacias* and sometimes not. Clump thickets occur on old termitaria in many of the drainages. Thickets are a notable feature of the country generally, and vary in size from the small termite-mound clumps to blocks of a square mile or more. *Rhus* and *Teclea* spp. are the most common thicket elements, but there is much variation in the other numerous constituents.

The 6–8 feet high grass cover of the country, consisting mainly of *Hyparrhenia* spp. and *Panicum maximum* is one of its main features. This long grass cover has a very marked effect on the distribution of the tsetse, as it makes small game animals invisible to them throughout most of the country during the greater part of the year. The grass is normally burned off during the late dry season, between December and February, but by June it has usually regrown to full height again. This means, in effect, that hunting as a tsetse control measure, except in special areas, can normally only be conducted effectively during the first six months of any year.

Development of the Tsetse Control Department and Policy

The many widespread tsetse advances had made it abundantly evident by 1940 that a much bigger organization was needed than the small entomological section of the Medical Department, containing but two European Officers, which had sufficed up to that time to deal with tsetse control problems of human (Gambian) sleeping sickness.

Owing to continued severe staff limitations it was not possible to do more in the early '40's than try to estimate the size of the problems created by the tsetse advances and give thought to possible ways of dealing with them. In both these respects extremely good progress was made in 1941–43. During this period extensive surveys were completed by T. W. Chorley in Acholi, Karamoja, Busoga and Mengo Districts, and a number of fundamental observations were made by him which were to have a profound effect on the future course of tsetse control operations in Uganda.

The first of these observations was that over wide areas the process of bush densification was making rapid progress. This was obviously making it progressively easier for *G. pallidipes* to extend its range. The second, and probably the most important observation, was that in the long-grassed country of Buruli, Mengo, Chorley noticed a very close association between the southward advance of *G. pallidipes* and seasonal large-scale southward movements of buffalo. A third observation was of the abundance of bush-pigs in the newly-infested parts of Buruli, which it seemed certain must provide a plentiful and readily available food supply for the incoming *G. pallidipes*.

While these initial surveys were in progress, it was decided by the Tsetse Committee which had been set up in 1942 that the Buruli, Mengo, advance was the most serious threat to the country, and that control of this must have first priority.

Active control measures first started in Buruli, Mengo, in 1944. As a result of the survey observations the measures instituted were:—

(*a*) Halting of the southward movements of buffalo in the first instance, supplemented from early 1945 onwards by general shooting of the smaller game animals.

(*b*) Controlled fierce late-burning of the country—to delay and if possible reverse the process of bush thickening, and also to make it easier to hunt out the game.

(*c*) Reduction in the bush-pig population by organized hunts with nets and spears by the local people.

(*d*) De-flying of southward road traffic.

Before the end of 1945 it became evident that the initial control measures were having a marked effect on the Buruli advances; and by mid-1946 it was confirmed beyond doubt, by fly-pickets and patrol catches, that not only had the *pallidipes* advance been successfully

halted, but there had been a definite northward retreat of the fly-front of at least ten miles. These were extremely heartening findings, for it could hardly be doubted that if measures of game elimination and late-burning could succeed against *G. pallidipes* they would also deal successfully with the recently-infested *G. morsitans* areas.

These early successes in Buruli, Mengo, in 1944–45 were directly responsible for the acceptance and development of game elimination, coupled with fierce late-burning and intensive pig-hunting, as the tsetse control method to be pursued in the recently-invaded long-grassed areas of Uganda against both *G. morsitans* and *G. pallidipes*.

On the inauguration of the separate Department of Tsetse Control in 1947—staffed at first by one entomologist, J. P. Bernacca, and six European field officers in addition to T. W. Chorley, and operating under the direction of B. I. Slaughter seconded from the Uganda Administration—ability to take action on a scale commensurate with the size of the tsetse problems at last became possible. The appointment of J. Y. Moggridge (formerly of the Tanganyika Tsetse Research Department) as the first substantive Director of the new Department in August, 1948, and the recruitment of three more field officers in that year completed the formation of an organization which was adequately staffed for dealing with the many and varied problems.

Organization of Hunting and Hunters

The fundamental bases on which the hunting organization in Uganda has been built up have been that only good shots should be employed, that they should be well paid, well equipped and closely supervised, and that each hunter should be provided with a labourer to do ancillary jobs so as to enable him to devote all his time to hunting. Tsetse control hunting under these conditions has in practice proved such popular employment—particularly with the Acholi tribe of born hunters—that the supply of would-be hunters, mainly former soldiers of the King's African Rifles, has always exceeded demand. This has made it possible to maintain an efficient and well-disciplined force of hunters in the field at all times: a force which reached a maximum strength of 250 in 1954.

A major factor in the success of the hunting operations has undoubtedly been the ability and keenness as hunters of the European Field Officers, many of whom, assisted by a number of capable African hunter overseers, have had charge of up to 100 hunters at a time.

At an early stage in the first hunting operations in Buruli, Mengo, division of the hunters into two complementary forces became the normal hunting practice. The job of the main body was to deal with the buffalo and other migratory animals and attempt to drive them out of the reclamation area. The task of the second force was to operate behind the main body and shoot out the smaller non-migratory game animals. Rearguard operations of this kind have commonly involved continuance of shooting of steadily dwindling numbers of the smaller animals for some years after the main buffalo herds have been removed, and it has been in these conditions that the system of close supervision and paying a good wage irrespective of numbers of animals shot has proved of the greatest value. In brief, this system has ensured that hunting has continued with enthusiasm until game densities have been reduced to a level low enough to effect complete eradication of the tsetse.

When J. Y. Moggridge assumed control of the Department in 1948 an efficient hunting organization including some 150 African hunters had already been built up. The main innovation introduced by him—a highly successful one—was the posting of groups of hunters to shoot out areas of tsetse concentration well in advance of the main lines of hunters. It cannot be doubted that by this means successful completion of some of the operations was speeded up by at least as much as a year. Nor can it be doubted that organized tribal pig-hunting was a further effective means of hastening eradication of the fly.

The hunting measures have included the killing of all the ungulate game animals save giraffe and roan antelope (which are very rare and very local) and, in some areas, the Uganda kob. When it has proved necessary to interfere with seasonal movement of elephants in the interests of tsetse control this has normally been the responsibility of Game Department hunters.

Since it was appreciated at the outset that land reclaimed from tsetse by hunting can, under normal conditions, readily be re-invaded by game and tsetse once active shooting operations cease, the policy adopted from the earliest days has been to hunt up to predetermined "consolidation lines"— lines across the former avenues of tsetse advance which could feasibly

be strengthened sufficiently by increased settlement of agriculturalists to prevent such reinvasion. To reach the chosen lines it has undoubtedly proved necessary to reclaim much more country than could be put to immediate use. But on ecenomic grounds this policy has proved fully justified by the shortening of the consolidation lines which has been achievable by hunting out the greater areas. In Acholi, for example, it is planned eventually to consolidate the reclamation of more than 1,800 square miles of country along a line not more than 20 miles in length.

Having determined where the consolidation lines could best be created continuous efforts have been made, and continue to be made today, to induce as much new agricultural settlement as possible—by such means as provision of water supplies, free transport, free food and exemption from poll-tax in the earlier years—so as to strengthen these lines sufficiently for them to stand on their own as effective tsetse barriers.

In the course of the hunting operations in Uganda the use of game fences to prevent reinvasion of cleared areas has never yet proved necessary. In our ability to do without such fences the fortuitous division of the country into a number of discrete blocks, more or less isolated from each other by large rivers and lakes, has undoubtedly been of great assistance. The best example of this was in Bugerere County, Mengo. There the presence of the Sezibwa River on one side and the Nile on the other—both being effective barriers to the crossing of most game animals—made it possible to reclaim 500 square miles of country from *G. pallidipes* by shooting from south to north on a front which nowhere exceeded 15 miles. In general the existence of such stretches of swamp and open water has meant that no "shooting front" has exceeded 70 miles.

Control by Game Elimination, 1945–1957

Buruli and Bulemezi, Mengo

Departmental hunting started with eight African hunters under Chorley's supervision in South Buruli, Mengo, in 1944. In succeeding years the number of hunters was progressively built up until in 1951—the last year of full-scale hunting in this area—they numbered 90. By the end of that year, 1951, it was clear that of the whole 2,500 sq. miles of country previously denied to cattle by *G. morsitans* and *G. pallidipes* in this region, all but a small area of some 150 square miles in the extreme north-west corner of Buruli had been fully reclaimed from resident tsetse. This corner of Buruli had meantime been shown to be invaded continuously by flies carried across the Nile by canoes from south Lango. By now, late 1957, the success of game elimination measures in south Lango had caused this immigration to cease and the whole 2,500 square miles is fully reclaimed from *G. morsitans* and *G. pallidipes.*

Total numbers of animals shot in the eight years 1944–51 to reclaim this broad stretch of country were 1,031 buffalo and 12,857 head of smaller game. Bushbuck (2,613) and reedbuck (2,892) were the most numerous animals shot. The only other animals of which more than 1,000 were killed were hartebeeste (1,089) and oribi (1,642). The yearly average of hunters, working normally for only seven months in each year on account of the long grass, was of the order of 45 to 50. Numbers of animals killed in tribal hunts during the reclamation period are unfortunately not known, though records show that in 1945, the first full year of tsetse control operations, such kills totalled 404 bush-pig and 652 other small game. Substantial reduction in game numbers by armed poachers, especially in north Bulemezi County, is also known to have occurred.

Examples of fly-catches illustrating the effects of game elimination in Buruli, Mengo, are given below:—

(*a*) At the Kalonge fly-picket, on the main north-south road near the southern edge of the reclamation area, the mean monthly catch of *G. pallidipes* was 38 in the second half of 1944. This catch dropped to a corresponding figure of 1.3 in 1947, and to nil by mid-1948.

(*b*) On a series of three fly-routes operated daily with bicycle-borne sticky screens in the north-western part of Buruli the results were even more dramatic. Hunting did not start in this region until 1948. The total monthly catch of *G. pallidipes* and *G. morsitans* for the three fly routes was 967 in January, 1949. By March, 1950, this catch had dropped to nil, and only four more flies (all *G. morsitans*) were taken during the following 19 months up to October, 1951.

By the time the Buruli invasion was halted in 1944–45 the total cattle population of the county had been reduced from 28,000 to 144, all of which lived in about 24 square miles in its extreme south-west corner. By the end of 1955 this county was again supporting cattle in large numbers, estimated to be not less than 22,000 head.

Bugerere, Mengo

This county was invaded in its south-east corner by *G. pallidipes* from south Busoga towards the end of 1943. The advance proceeded northwards through Bugerere so rapidly that the last few cattle remaining in the extreme northern tip of the county, some 50 miles from the point of entry of the fly, were exterminated by trypanosomiasis in December, 1944. Prior to this invasion the cattle population of Bugerere had been more than 9,000. The total area of land denied to cattle by this *pallidipes* advance was something over 500 square miles.

Reclamation by hunting from south to north was started in 1945, but two years later this operation had to be temporarily suspended on account of a greater need for the (then small) hunter force elsewhere. This was to combat the threatened further advance of *G. pallidipes* south-westwards from Bugerere through the northern part of Kyagwe, into Bulemezi County, Mengo, which has been mentioned earlier as giving rise to a serious risk of further spread of Rhodesian sleeping sickness over a wide area. This threat having been successfully dealt with by hunting in 1947–49, full-scale hunting in Bugerere itself was restarted in 1950, and succeeded in starving out the Bugerere *G. pallidipes* completely by the end of 1952.

Totals of animals shot by tsetse-control hunters in this narrow stretch of country between the Nile and Sezibwa rivers were 293 buffalo, 69 hippopotami and 2,178 smaller animals. As in Buruli, tribal hunts accounted for quite large kills in the earlier years of the control operations, but details of such kills in later years are again unknown.

Since Bugerere was freed of *G. pallidipes* in 1952 the cattle population has built up again to nearly 4,000 head.

Acholi

It was not until 1946 that any action—other than careful survey of tsetse distribution—could be taken against *G. morsitans* in Acholi District. By that time the advance which had started southwards along the Aswa Valley in about 1941 had evicted cattle from 1,800 square miles of country. In so doing it had become linked across the S.E. border of the District with the southward Karamoja *morsitans* advance, and had also penetrated some way southwards into the northern part of Lango District.

The first necessity was to halt this southern advance into the highly important cattle-producing district of Lango. To do this only 12 rifles were available in the early part of 1947, but by the end of that year the procurement of more rifles had made it possible to increase this number to 36, and eventually, by 1949, 115 hunters were employed on this operation.

Before the Acholi hunting started the main concentrations of *G. morsitans* were known to occur in an area extending from 10 to 40 miles eastwards and southwards from Gulu, in which three tributaries of the Aswa River, the Dawa, Chome and Larwodo also harboured *G. palpalis* in considerable density. So effective was game elimination in the Acholi area that *G. morsitans* had been eliminated entirely from everywhere south of the Gulu–Kitgum road (*see* map) by early 1951. In this area some bush-clearing was done, but this was undertaken mainly as an anti-*G. palpalis* measure to control human sleeping sickness. Since it so happened that the main focal areas of both tsetses occurred in the same region it cannot be doubted that this bush clearing speeded up the eviction of *G. morsitans* to some extent. But the rapid success of the Acholi operations must, we believe, be attributed to the adoption early in the campaign of the Moggridge technique of "hunting out" the areas of fly concentration well in advance of the main lines of hunters moving from south and east to north and west.

Totals of animals shot by departmental hunters to reclaim this extensive tract of country were 855 buffalo and 10,128 smaller animals. In this *G. morsitans* area it is interesting to find that bushbuck comes well down in the list with a total kill of only 971. The most numerous kills in Acholi were hartebeeste (2,810), oribi (1,696), duiker (1,338) and waterbuck (1,334). Tribal hunting is a prominent feature of native life in Acholi. No valid estimate of the total numbers of animals killed on tribal hunts in the tsetse reclamation area

during the period 1947–1951 can be given, but it is known that the numbers so killed exceeded 6,000 during the first two years.

A feature of the Acholi results was that so long as even a few rhinoceros remained in the Dawa–Chome area (and there were never more than 12), an occasional *G. morsitans* could always be picked up. For some time it did not prove possible to obtain permission to shoot these animals, but eventually this was allowed, and no tsetses were caught in the area after the last rhinoceros had been killed in February, 1951.

Examples of fly-round catches from the Acholi area are as follows:—

(*a*) *Rackoko*: (Eastern part of control area).—Route A produced 443 *G. morsitans* in the last six months of 1947. Corresponding catches in the next three years were 317, 61 and 5, with the last fly being taken in September, 1950.

(*b*) *Dawa-Chome*: (Western part of control area).— In this, the region of highest initial *G. morsitans* densities, the results of control operations were most dramatic. The four continuously-operated fly routes produced 441 *G. morsitans* in the last half of 1949, 40 during the next six months, and only two in the second-half of 1950 (one in July and one in August).

In terms of changes in cattle numbers it is not possible to give any accurate assessment of the effects of the Acholi tsetse invasion and subsequent reclamation. But it was estimated that in the whole district there were 102,000 head in 1938. Between then and 1944 numbers dropped, as a result of rinderpest and heavier than normal (war-time) culling in addition to tsetse, to 47,000. By 1951 the district total was up again to 69,000 and by 1955 to 84,000. Some of the increase since 1944 is certainly due to improved disease control and cattle management but much of it can only be ascribed to the successful control of *G. morsitans*.

Maruzi and Kwania, Lango

Eastward advances of *G. morsitans* and *G. pallidipes* in the southern and western parts of Maruzi and Kwania counties of Lango District during the 1940's had culminated by 1951 in a potentially serious threat to the cattle-producing Kyoga county of the same district. By this time the total area infested in the former two counties was approximately 700 square miles.

Reclamation of the Maruzi–Kwania tsetse belt started in 1953 with a series of aerial applications of DDT, by the Colonial Insecticide Research Unit, to the most easterly 40 square miles of the fly salient. This spraying was, it is gratifying to record, immediately successful in halting the advance. At the same time as the spraying was in progress the reclamation of the rest of the salient by game elimination was commenced. This operation is still in progress, and at the time of writing this paper has succeeded in eradicating tsetse from all of the eastern half of the former salient, and reducing numbers to very low levels in the western half.

Buruli, Bunyoro

It will be seen from the map that it was from Buruli, Bunyoro, that the invasion of Mengo District by *G. morsitans* took place. By the time the reclamation of the northern parts of Buruli and Bulemezi, Mengo, was nearing completion it was realized that the reclamation of Buruli, Bunyoro should also be undertaken, (*a*) as a means of consolidating effectively the north Mengo reclamation work, and (*b*) because of the need for more grazing in Bunyoro District itself.

Game elimination in Buruli, Bunyoro, up to the predetermined consolidation lines shown on the map, was commenced in 1951. This operation is also still in progress (and includes, as shown, a small area in the north-west corner of Singo County, Mengo). To date more than 600 of the 800 square miles involved have been fully reclaimed.

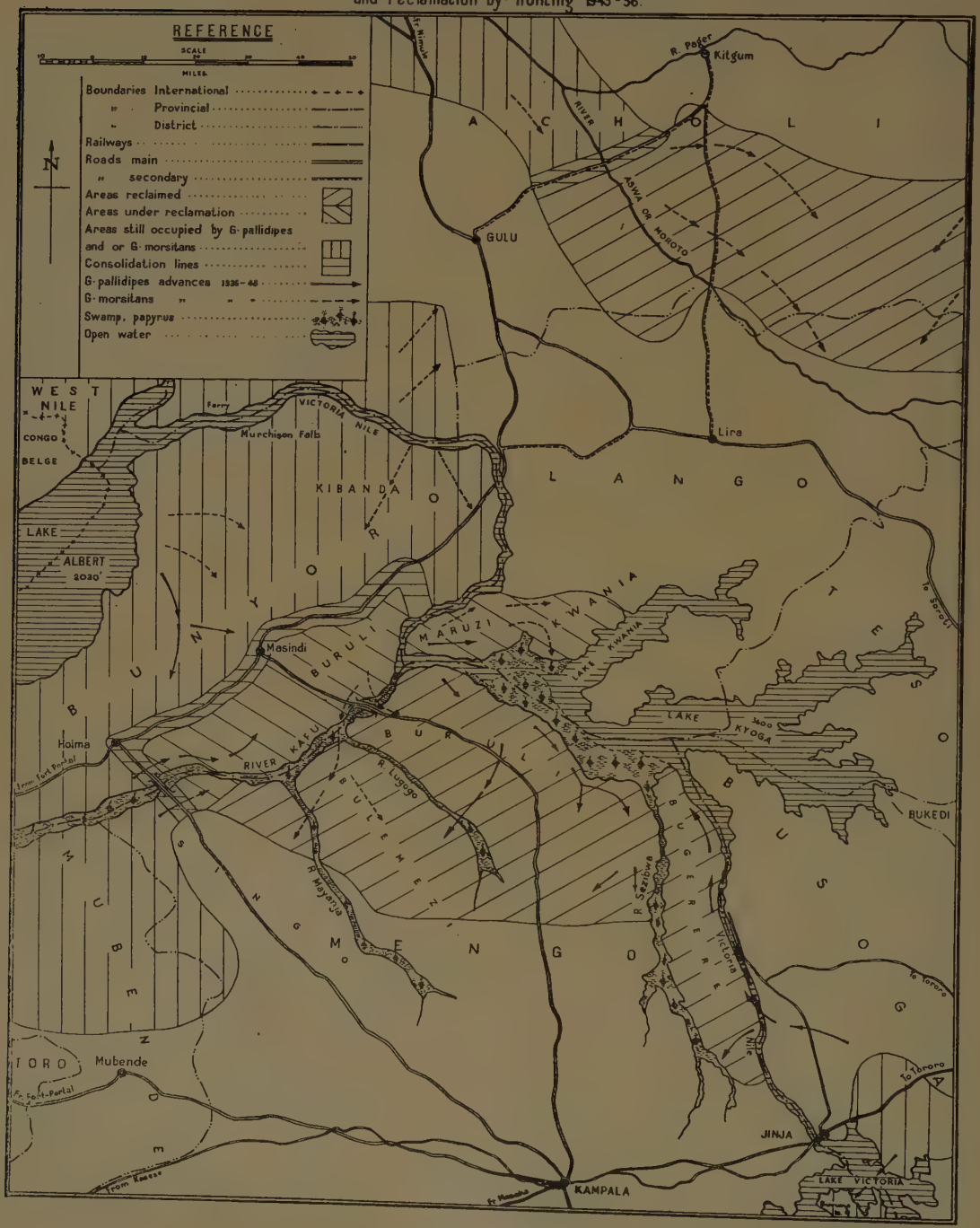
SUMMARY OF GAME ELIMINATION RESULTS

To summarize these results it can be said that, with a strictly limited amount of assistance from subsidiary bush clearing, the application of the tsetse control measures of game elimination in the long-grassed *Combretum* savannah areas of Central Uganda, during the years 1945–1957, was successful in—

(*a*) halting at least two major advances of *G. pallidipes* and one of *G. morsitans*, which between them constituted extremely serious threats to the cattle industry of the Protectorate and also, by threatening to spread Rhodesian sleeping sickness from the area of the 1941–42 outbreak in south Busoga, to the health of the people in the greater part of Buganda;

CENTRAL UGANDA.

G. pallidipes and G morsitans advances 1935-45
and reclamation by hunting 1945-56.



(*b*) reclaiming entirely from *G. morsitans* and *G. pallidipes* some 4,800 square miles of country, consisting of—

(i) 2,500 square miles infested by *G. pallidipes* and *G. morsitans* in Buruli and Bulemezi, Mengo District;

(ii) 500 square miles infested by *G. pallidipes* in Bugerere, Mengo District;

(iii) 1,800 square miles infested by *G. morsitans* in Acholi District;

(*c*) making good progress in the reclamation of—

(i) 700 square miles from *G. morsitans* and *G. pallidipes* in Maruzi–Kwania, Lango District;

(ii) 800 square miles from *G. morsitans* and *G. pallidipes* in Buruli, Bunyoro District.

Totals of animals shot by tsetse control hunters to achieve these results in the fully reclaimed areas were 2,179 buffalo, 69 hippopotami, 10 rhinoceros and 25,163 smaller game animals. Bushbuck, which have been shown to be a specially favoured food of *G. pallidipes,* gave the most numerous kills of the smaller game animals, with a total of 4,901. On the basis of a total hunting area of 4,500 square miles these figures give a mean kill of all animals per square mile of almost exactly six.

Costs

The costs of the actual field work, in terms of wages and rations of tsetse control hunters and other African field staff, have worked out at approximately 60 cents (7d.) per acre of country reclaimed. But when full account is taken of all administrative overheads, including transport, equipment and stores, a valid figure for the total reclamation cost by game elimination is considered to be approximately Sh. 2 per acre. Since so much of this reclamation has been undertaken against *G. pallidipes*—whose habitat can well cost up to Sh. 60 or more to clear by bush-felling—we are firmly convinced that in the circumstances prevailing no other known testse control measures could have achieved so much in so short a time, nor could any other method have been successfully applied at so low a cost.

Conclusion

Veterinary statistics show that the total cattle population of Uganda increased between the years 1945 and 1956 from 2,294,000 to 3,094,000—an increase of 800,000 cattle, worth at current prices about £10,000,000. It is quite certain that a high proportion of this satisfactory increase in the wealth of the Protectorate can be ascribed to the success of the testse control game elimination measures described in this paper.

CHEMICAL WEED CONTROL IN LUCERNE BY MEANS OF "ACTIVATED" DNBP

By D. M. Rocco, P.O. Box 38, Naivasha, Kenya

(*Received for publication on 6th November, 1957*)

The control of weeds in lucerne has always been one of the major factors limiting the acreage that could be established in any one year and the total acreage that could be put under lucerne on a farm in Kenya. This was principally due to the fact that the lucerne had to be weeded by hand, and that it took anything from 60–100 woman days to clean an acre of seedling lucerne and another 30–50 woman days annually to keep the established lucerne free of weeds. In addition, as the greatest quantity of weeds was to be found during the rainy season, when there is the greatest amount of work to be done on the farm, it can be appreciated, that unless a very large labour force was kept solely for that purpose, the acreage of lucerne that could be maintained was limited, in the writer's case to 120 acres, of which not more than 30 could be replanted or developed in any one year. It was with this problem in mind that one of the larger companies dealing in herbicides was approached in 1954 in order to see whether any herbicide existed on the market that would make this task easier.

The principal type of weeds that had to be contended with were: *Galinsoga parviflora, Amaranthus* spp., *Chenopodium, Datura stramonium, Nicandra, Malva* spp. and *Argemone*. All these were to be found both in the seedling and in the established lucerne.

The first trials were carried out in October, 1954, with the ammonium salt of DNBP (2-sec butyl—4-6 dinitro phenol), on flood-irrigated lucerne. A high-volume high-pressure sprayer was used, as it was considered at that time, that DNBP would only be effective if applied at 100 gallons per acre at a pressure of 200 lb. per square inch, but results were most disappointing, as even at rates of 2 lb. acid equivalent per acre the weed kill was not higher than 25 per cent.

During 1955 the triethanolamine salt of DNBP was sent to the writer for trial, as it was considered to be far more effective than its predecessor. Results were better, but the rates that had to be used were such as to render the operation completely uneconomical.

Several trials with various chemicals and different techniques were undertaken in 1956, with little or no result, and it was not until the new phenoxybutyric formulations were produced that any progress was made. Both 2,4D-B (2:4-dichloro-phenoxybutyric acid) and MCPB (2 methyl—4 chloro-phenoxybutyric acid) were tested. It was found that the 2,4D-B formulation was the most efficient as well as showing less toxic effects in the lucerne.

During the year 1957 trials on a larger scale were undertaken. At the beginning of the rainy season an 18-acre field was planted to lucerne and 14 days after germination a series of field trials were set up. Half the field was sprayed with 2,4D-B, at rates varying from ¼ lb. to 1 lb. acid equivalent per acre in 30 gallons of water. The other half was sprayed with a 2,4D-B/DNBP (triethanolamine salt) mixture.

The 2,4D-B alone gave excellent control of the seedling weeds, particularly *Amaranthus, Chenopodium* and *Datura; Galinsoga* and *Malva* were less affected, although after some weeks much of the *Galinsoga* was seen to be dying. It was to control *Galinsoga* that the 2,4D-B/DNBP mixture was tried and found to be effective at the rate of 0.75 lb. 2,4D-B and 0.6 lb. DNBP acid equivalent per acre in 30 gallons of water.

It was considered that one of the principal reasons why the DNBP was more active on this trial than previously was due to the fact that the weeds had been sprayed during a period of heavy rainfall which had caused soft weed growth.

Although these trials solved many of the problems of controlling weeds in seedling lucerne, the chemicals mentioned in the previous paragraphs had little or no effect on more mature weeds that had been cut several times with the lucerne. In discussion with a herbicide research botanist, we came to the conclusion that one of the possible reasons why the DNBP had proved less effective here in Kenya than in the United Kingdom was that the water used was highly alkaline (400 parts per million expressed as $CaCO_3$) with a pH of 8-9.

It was suggested that part of the efficacy of the DNBP was lost, due to its having to neutralize the water. Several tests were then undertaken, adding sufficient concentrated sulphuric acid to the DNBP solution not only to neutralize the water but also to acidify it slightly. These trials proved very much more effective than any undertaken previously, as, using a Chesterford logarithmic sprayer, good control of weeds could be observed at rates far below what had previously been considered the absolute minimum for any effective treatment. As the sulphuric acid could not be used in a normal spray tank it was decided to use sulphate of ammonia as an activator.

The reasons for this extraordinary increase in the efficacy of the DNBP are not yet clearly known. So far, several suggestions have been put forward, among which, two may be considered as being the most probable.

(1) It is probable that the sulphuric acid activator increases the H-ion concentration of the spray deposit on the leaf surface. This, according to Robbins, Crafts and Raynor (1952), would increase the solubility of the DNBP in the fatty cuticle of the weeds, and once having entered, the DNBP acts as protein coagulant.

(2) It is, however, also possible that the NH_4 ions are selectively absorbed by plant tissues. In that case, it seems reasonable to assume that in the case of the application of ammonium sulphate, there is a gradual increase in the H-ion concentration on the leaf surface. If this be so, then the action of the sulphate as well as that of the acid may in the end be the same. It is not unreasonable to assume that as the spray drops evaporate and the acid concentration rises, serious physical damage to the cuticle may be done, thus facilitating the entry of the DNBP into the plant cells.

Trials carried out showed that this was an excellent method of controlling weeds in lucerne, particularly when dealing with adult plants. It has been the experience of the writer that a rate of 0.4 lb. acid equivalent per acre of DNBP (triethanolamine salt) plus 4 lb. of ammonium sulphate give optimum results in the control of most species of weeds as well as being an economically sound proposition. A comparison of costs will be made at the end of this paper.

Excellent control of *Galinsoga, Datura stramonium, Nicandra* and *Chenopodium* is to be seen in all fields that have so far been sprayed. *Amaranthus* and *Argemone* are checked, but there are no effects beyond a slight scorching of the leaves to be seen on *Malva*. The lucerne shows little or no sign of being affected provided it is sprayed within seven days of cutting. Spraying later shows a considerable scorch on the leaves but the plant shortly grows out of it. As a matter of fact, the lucerne plants seem more vigorous than before, although whether this is due to the absence of weed competition or to the boost given by the ammonium sulphate is as yet unknown.

As most of the trials had been carried out during or just after the last rainy season the control of weeds during a period of drought, which would produce hard weed growth, was still an unknown factor. The latest trials undertaken when there had been no rain for several weeks, and day temperatures were very high, seemed as good as those done previously.

A recent trial, undertaken in lucerne with a heavy infestation of *Amaranthus*, has brought about another aspect of "activation" which may prove of great interest in the future. In this trial 0.2 lb. acid equivalent per acre of 2,4D-B were added to the normal mixture of 0.4 lb. acid equivalent DNBP plus 4 lb. ammonium sulphate The effect of the 2,4D-B on the *Amaranthus* was much more marked than in any previous trial, where adult *Amaranthus* had stood up to it with little or no damage. In this case even weeds which had stood up to 2 ft. high before cutting, and were over six months old, showed the characteristic effects of the hormone herbicides at the base of the plant. It is the writer's opinion that the greater penetration of the activated dynotox into the plant tissues has enabled the 2,4D-B to act on plants which would otherwise have been protected by their hard and woody growth. Should this be so, and only further research will prove it, the rates at present applied may be greatly reduced.

In conclusion, the writer has found that, not only has it been possible to keep the lucerne clean at a more economic rate than previously, but it has also meant that the expansion of the lucerne plant can be carried out at a far faster rate. It has been possible this year to establish 62 acres of lucerne using a total of 525 woman days to remove the herbicide resistant weeds and grasses. In addition, a further 84 acres of established lucerne has been sprayed and subsequently rapidly cleaned by hand. It is planned next year to establish a further 150 acres of lucerne, thus bringing the total to

nearly 300 acres. This should produce approximately 200 tons of dried lucerne hay or meal per month.

A table of figures, herewith, may give the reader an idea of what saving the chemical control of weeds in lucerne has meant to this farm.

COST OF WEEDING ONE ACRE OF LUCERNE BY HAND
(Spread over a five-year period)

	Sh. cts.	*Sh. cts.*
Weeding of lucerne from seedling stage to establishment, 65-100 woman days at 1/50	97 50—	150 00
Weeding of established lucerne over five years, 150-250 woman days at 1/50	225 00—	375 00
Total cost of weeding one acre ..	322 50—	525 00
Average	423 75	

COST OF WEEDING ONE ACRE OF LUCERNE
(Herbicide plus hand labour)

	Sh. cts.	*Sh. cts.*
Spraying seedling lucerne 2,4D-B plus DNBP	38 50—	38 50
Hand weeding after spraying at 8-10 woman days	12 00—	15 00
Spraying activated DNBP over five years	192 00—	192 00
Hand weeding after spraying, 8-10 woman days per annum	60 00—	90 00
	302 50—	335 50
Average	318 25	

REFERENCE

Robbins, W. W., Crafts, A. S., and Raynor, R. N. (1952). "Weed Control—a textbook and manual", published by McGraw-Hill Book Company, New York, p. 146.

REVIEW

GOAT HUSBANDRY, by David Mackenzie, published by Faber & Faber Ltd., London, 1957, pp. 349, price 36*s*.

Present and prospective goat-keepers will welcome this book as filling a long-standing gap in the literature on the goat. There are chapters on the control of the animal, its housing, general nutrition, feeding, breeding and care in case of disease or accident. Tables of the nutritional values of various feeds and herbs are available, also a useful bibliography and index.

Mr. Mackenzie, in general, stresses the economic aspects of goat-keeping throughout his book. He contends that the goat can profitably fill a place in modern farming, points out the suitability of the animal for the utilization of waste land and industrial waste products, and generally suggests many ways in which goat's milk may be utilized on the farm or brought to the notice of the public. This is further supported by an account of the medicinal properties of this milk, and of its successful use in medical practice.

Although the book is written mainly for the conditions prevailing in Britain, there are many basic aspects which will hold good in any country, if properly translated to the local conditions. Mr. Mackenzie would appear to have made considerable study both of the history of the animal and of the conditions under which it is maintained in other countries, and many parts of the text and of the appendices will be found of interest to the various goat-keeping areas of the world.

K.L.

A LAND USE MAP OF KENYA

By George A. Petrides*, Michigan State University, East Lansing, Michigan, U.S.A.

(*Received for publication on 12th December, 1957*)

In making a study of wild life conditions in Kenya in 1953–54†, it was necessary to ascertain present land use in the Colony and no land use map was found to be available. Fortunately, the map entitled "Kenya—Political and General" (Survey of Kenya. 1951), indicated the extent of the European areas, native reserves, forest reserves and National parks and reserves. The Troup Report (1953) subdvided the European districts into areas of cultivation and ranching. The extent to which native reserves and Crown land were devoted to cultivation or grazing seemed cartographically unrecorded, according to conversations with officials of the Department of Agriculture and the African Land Development Unit.

The areas of possible native cultivation in the reserves and on Crown land were first appraised from rainfall maps, especially those on the probabilities of 20-in. and 30-in. rainfall which have been prepared by J. Glover and P. Robinson (E.A.A.F.R.O., 1953). These areas of possible cultivation were then compared with the several available topographic quadrangles of the Survey of Kenya, Nairobi, on which some areas of African cultivation are marked, and on which the areas of dense population usually associated with cultivation could be distinguished from areas of less dense population.

Further checks were made through reference to the Survey's file of aerial photographs, though not all areas have been photographed, and those for some districts were not available for study.

The coastal districts of native cultivation were ascertained through combined reference to aerial photographs and to land use maps of P. E. Glover of the Veterinary Department of Nairobi. Correspondence with A. V. Bogdan of the Pasture Research Station at Kitale provided further information for the lands near there but north of the European zone.

The map is an attempt to show only the primary use of the land, within the several general categories chosen. That livestock grazing often occurs in conjunction with cultivation is recognized, but its consideration was not necessary for present purposes. All of the vast arid and semi-arid districts, particularly in the north and east, are considered to be grazed at least seasonally. Though there is a possibility that some areas are entirely unihabited and unvisited, it seems unlikely that they are large. Even in the areas infested by tsetse flies, according to P. E. Glover of the Veterinary Department (in conversation), there is usually some grazing of sheep or even cattle so that those, too, may be classed as grazing lands.

The National Parks, for all practical purposes, are grazed only by wild animals, but National reserves remain open to native occupation, and often intensive grazing.

It is not thought that this land use map is a final product. It is presented in the hope that its publication will encourage those with greater access to agricultural records to issue improved and refined editions.

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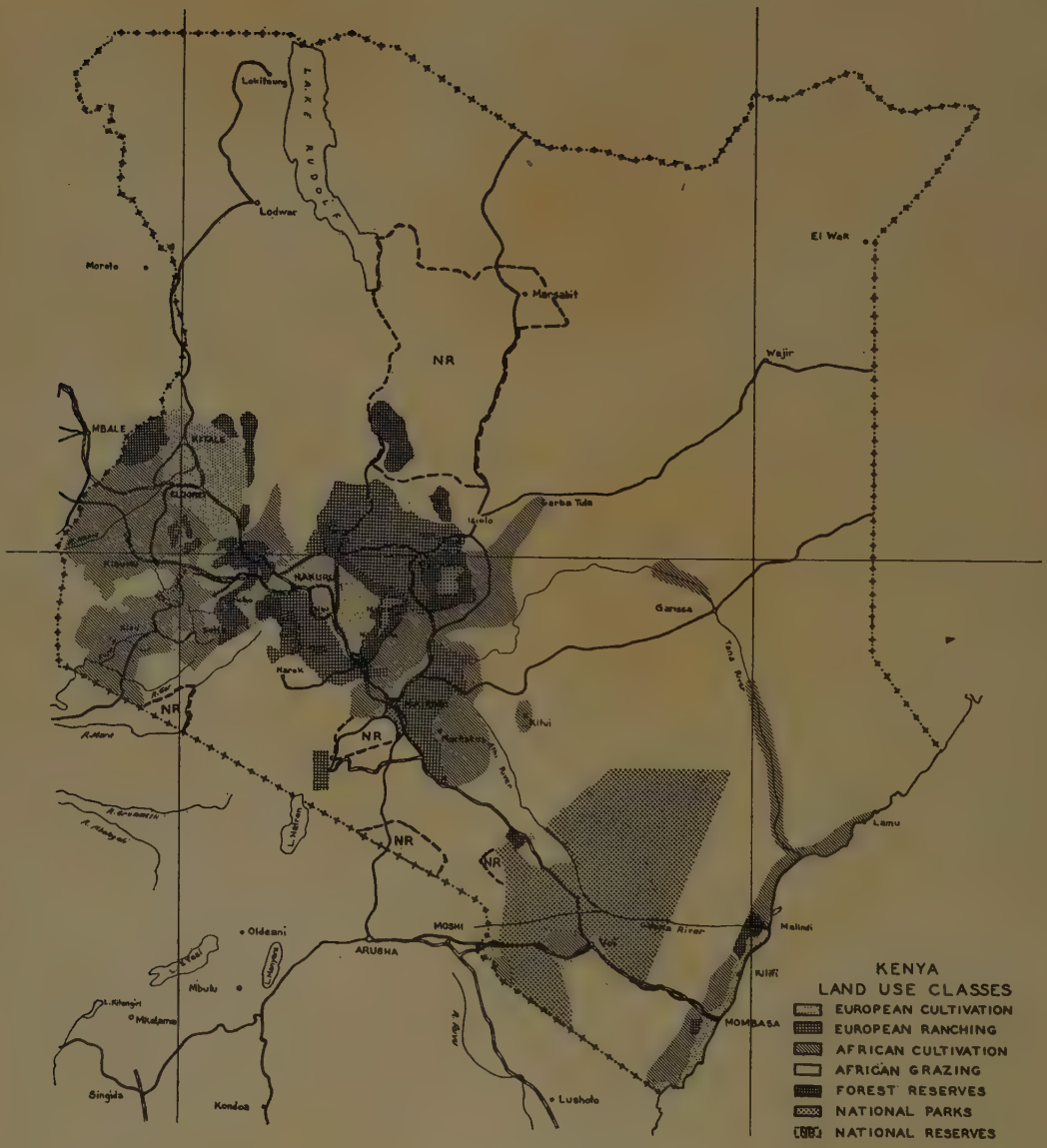
Survey of Kenya (1951). Kenya—Political and General. First edition, Government Printer, Nairobi.

Troup. L. G. (1953). Report into the general economy of the Highlands. Government Printer, Nairobi.

* Working under a United States Fulbright Research Grant with the Royal National Parks of Kenya and the East African Agricultural and Forestry Research Organization.

† *Kenya's Wild Life Resources and the National Parks*, published by the Trustees, Royal National Parks of Kenya, 1955, 24 pages.


Lokitaung
LAKE RUDOLF
Lodwar
Moroto
Marsabit
NR
El Wak
Wajir
MBALE
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Kisumu
NAKURU
Karek
Isiolo
Garba Tula
Garissa
Tana River
Kitui
NR
NR
NR
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Lamu
Oldeani
MOSHI
ARUSHA
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Mbulu
Singida
Kondoa
Lushoto
KENYA
LAND USE CLASSES
EUROPEAN CULTIVATION
EUROPEAN RANCHING
AFRICAN CULTIVATION
AFRICAN GRAZING
FOREST RESERVES
NATIONAL PARKS
NATIONAL RESERVES

THE RELIABILITY OF THE MAIN RAINS IN KENYA

By Joan M. Kenworthy and J. Glover, E.A. Agriculture and Forestry Research Organization

(*Received for publication on 10th October, 1957*)

It has already been shown (Glover and Robinson 1953a and b) that it is possible to derive a simple estimate of the reliability of rainfall for both annual and seasonal amounts, and provisional maps of the reliability of annual rainfall in East Africa have been published (Glover, Robinson and Henderson, 1954). These maps were used in the Report of the Royal Commission, 1953–1955, as a basis for an assessment of the agricultural potentialities of the three territories, whilst similar maps have since been published on a larger scale by the East African Agriculture and Forestry Research Organization. The object of this paper is to illustrate, with a series of three maps, the reliability of the main rains in Kenya and adjacent parts of Tanganyika.

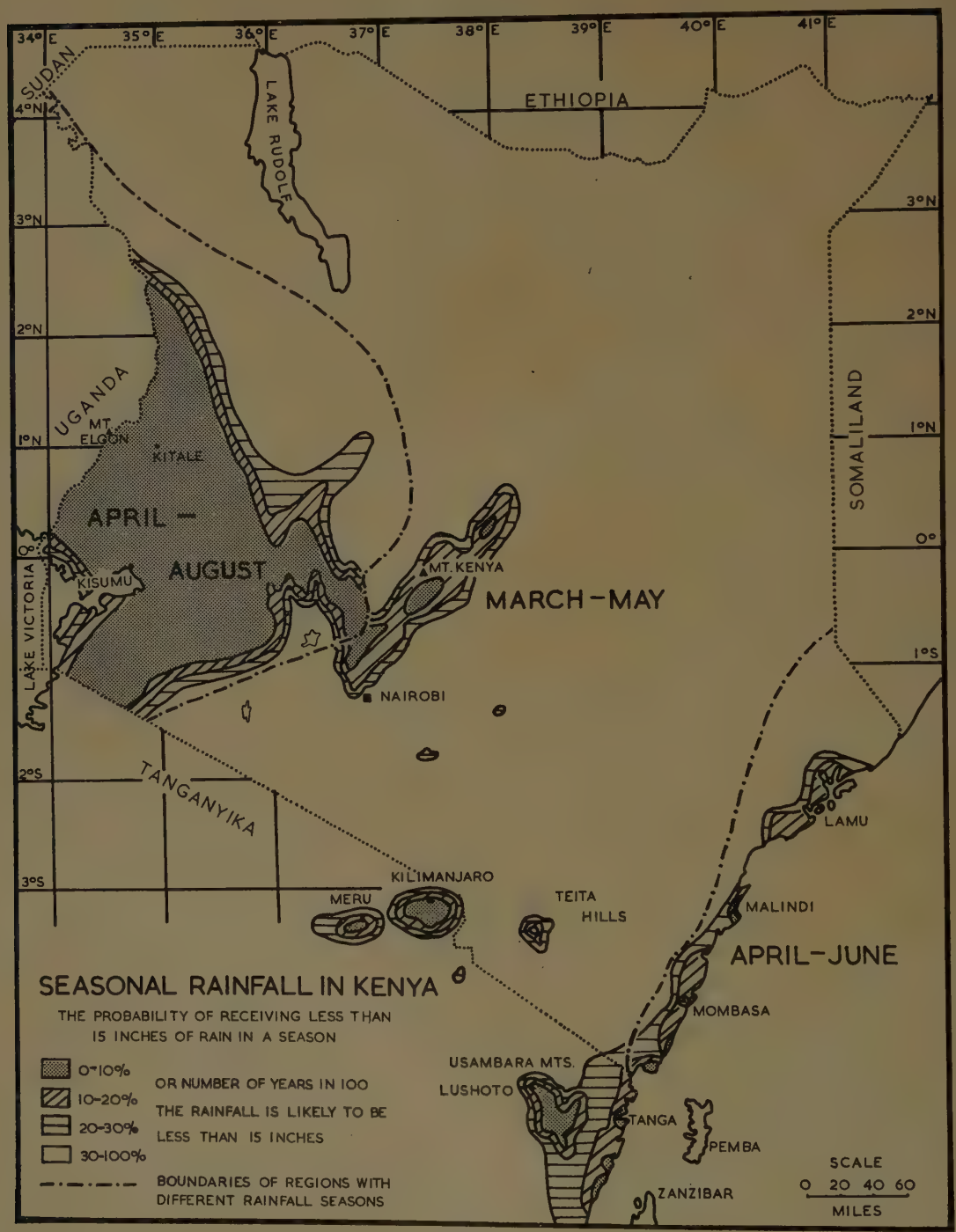
The climate of much of East Africa is characterized by its well-defined alternating wet and dry seasons. Since in many areas the rainfall is both marginal in amount and restricted in season, its variability is more critical than in many countries in temperate latitudes. The natural vegetation is often well adapted to the irregular rainfall and, whether in or out of its expected season, a few consecutive showers may produce a green and colourful landscape. In fact, the speedy utilization of the rainfall by the herbaceous vegetation may be misleading and give a more favourable impression of the amount of rainfall and the luxuriance of the vegetation than is actually the case. The farmer, on the other hand, is entirely dependent on receiving enough rain to satisfy his crop requirements within the set period of the growing season.

By analysing the rainfall records for an area, it is possible to estimate the reliability of a particular pattern of rainfall within the growing season (Glover and Robinson, 1954). Some idea of the most suitable planting dates may also be derived from the range of variation of the arrival of the rains, as for example Evans (1955) has shown in Southern Province, Tanganyika, where the rains frequently begin in November, but are not sufficiently reliable in amount for planting until mid-December. It is impossible, however, to show, even on a series of maps, the innumerable local variations in rainfall distribution and intensity, and the purpose of these maps is merely to give some idea of the distribution of areas where at least 15, 20 and 25 inches can be expected in the growing season.

The Seasonal Distribution of Rainfall in Kenya

The seasonal rains of Kenya are associated with the oscillations of the Equatorial trough of low pressure following the movement of the overhead sun and the resulting changes in patterns of air-flow. Theoretically the distribution of rainfall should then be simple—two wet and two dry seasons near the Equator, where the sun passes overhead in March and September, with a tendency towards one wet and one dry season in the north, where towards the Tropic the sun passes overhead twice, but with a shorter intervening period. In practice, however, the two rainy seasons are not everywhere distinct, even on the Equator. The rains are extremely variable both in time and space and the seasonal distribution of rainfall is complicated. Walter (1952) has shown that the monthly progression of the rain belt is not regular and suggested that paths of movement may change from year to year in relation to different patterns of airflow. There is as yet no simple explanation of these variations, and for a discussion concerning recent concepts of synoptic situations which might influence rainfall the reader is referred to a paper by B. W. Thompson (1957).

Few individual years fit the average picture of the monthly distribution of rainfall and some months are more variable than others. An attempt has been made, however, from the monthly means, to define what seasonal distribution of rainfall is characteristic of each area in order to decide what length of growing season is available. When it was not clear from the mean rainfall régime which months could generally be regarded as wet months, the mean monthly rainfall was compared with its standard deviation, and if the standard deviation was less than some 50 per cent of the mean (in many cases less than 30 per cent) that month was included as part of the rainy season. No station with a record of less than ten years was considered.


34° E
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SUDAN
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LAKE RUDOLF
ETHIOPIA
UGANDA
MT. ELGON
KITALE
APRIL – AUGUST
KISUMU
LAKE VICTORIA
MT. KENYA
MARCH – MAY
NAIROBI
TANGANYIKA
KILIMANJARO
MERU
TEITA HILLS
SOMALILAND
LAMU
MALINDI
APRIL – JUNE
MOMBASA
USAMBARA MTS.
LUSHOTO
TANGA
PEMBA
ZANZIBAR
SEASONAL RAINFALL IN KENYA
THE PROBABILITY OF RECEIVING LESS THAN 15 INCHES OF RAIN IN A SEASON
0-10%
10-20%
20-30%
30-100%
OR NUMBER OF YEARS IN 100 THE RAINFALL IS LIKELY TO BE LESS THAN 15 INCHES
BOUNDARIES OF REGIONS WITH DIFFERENT RAINFALL SEASONS
SCALE
0 20 40 60
MILES

Fig. 1

The area west of the Rift Valley is characterized by one long almost continuous rainy season. Most of the rain falls from April to August although the end of March is sometimes wet. September and October are drier months, but there is a secondary maximum in November. The November rains are very unreliable, but sometimes quite high, and may be disastrous for a wheat crop, although maize is not often adversely affected. From April to August variability decreases with increasing amount, but in November the standard deviation increases simultaneously with the mean, sometimes giving a high rainfall for the month, and sometimes very little.

East of the Rift Valley two distinct rainy seasons are characteristic, from March to May and from October to December. The first rains, the "long rains" are more reliable and greater in amount than the second or "short rains".

Between the one-season area west of the Rift and the two-season area to the east, there appears to be a transition zone along the Rift Valley and the Aberdares. Moving eastwards from the west highlands into the Rift Valley a more distinct intermediate dry season develops as June becomes drier on average, whilst on the Eastern slopes of the Aberdares and Kiambu the August rains bridge the gap between the two separate seasons characteristic further east. These are the rains known to some Africans as the "bean rains" and are actually used for a subsidiary bean crop. Even where there is no great increase in the mean rainfall for August the variability decreases and the mean though small is more dependable.

Yet another change in the seasonal distribution of rainfall is significant, where along the coast as far south as the Kenya border, April to June is characteristically the wet period rather than March to May. Further south in Tanganyika, March to May is again the main season along the coast and inland, although there is a transition zone here towards the December to May rains of southern Tanganyika, so that in this region the "short" rains of November and December may also be important.

The Probability Maps

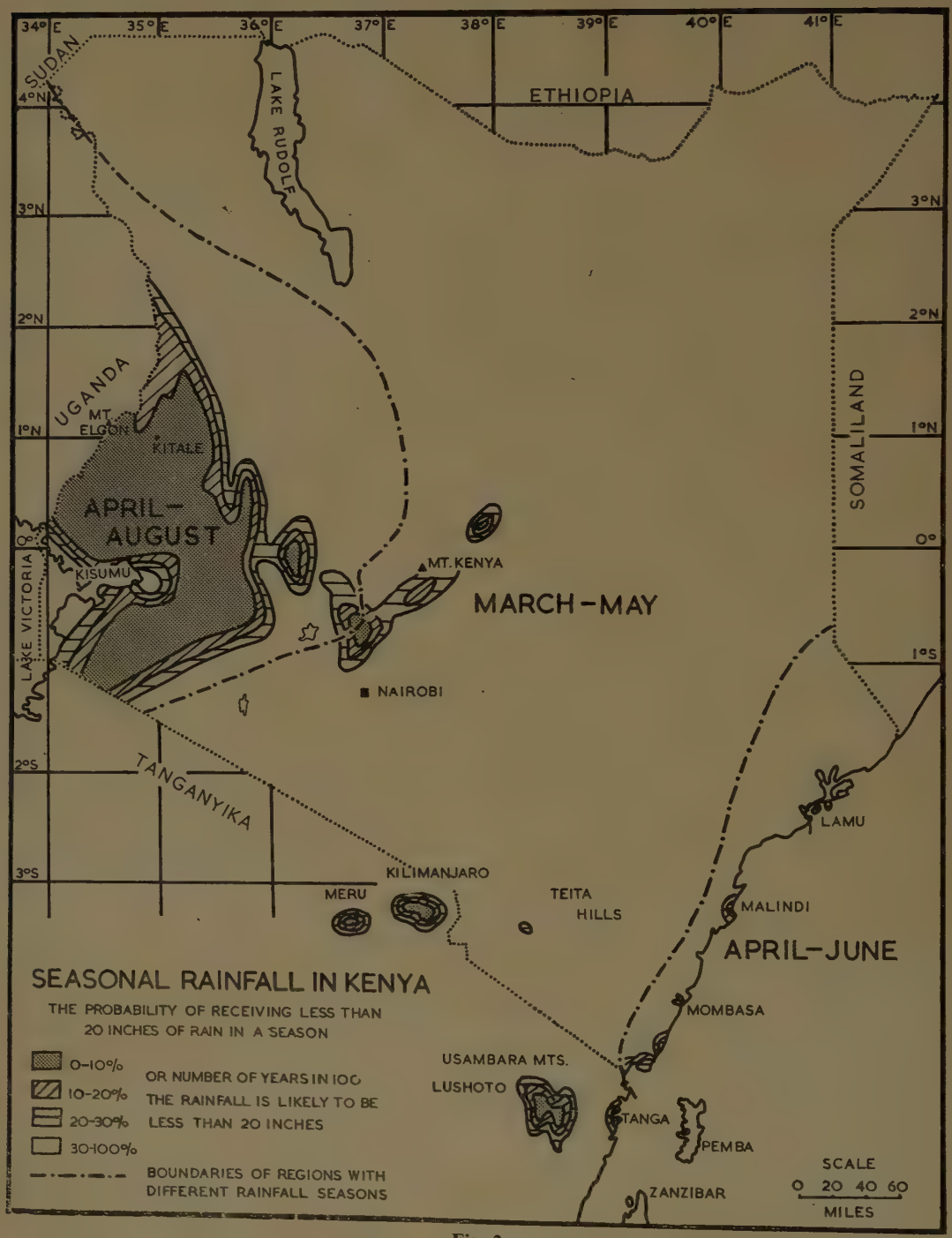
The maps have been divided into three regions and the reliability of rainfall estimated for the main growing season characteristic of each. To the west of the Rift Valley, crop production will depend on the rains from *April to August*, whilst east of the Rift Valley only three months from *March to May* are the most important. If crop requirements are not satisfied in these months, to expect to make up for deficiencies in other months would be entailing considerable risk.

The boundary between these two regions has actually been drawn to follow the Aberdares, so that most of the areas with rains transitional between March to May and April to August have been included in the region with an April to August rainfall season. Although the boundary is arbitrary, the change in characteristic season is fairly rapid and there is relatively little inaccuracy involved. The boundaries between the regions are not drawn, however, with any great accuracy in the dry areas, owing to the scarcity of observations, but a change there in the months considered would not alter the general picture of dryness and unreliability.

March to May is the main season for the whole of eastern Kenya except for the coastal strip where April to June is the wet period, and north-east Tanganyika has also been included to show the reliability of rainfall from March to May.

Three maps have been drawn and two of them, showing the probability of receiving less than 15 inches and less than 20 inches in a season, cover the whole area (Figures 1 and 2). Four levels of reliability have been chosen, 0–10 per cent, 10–20 per cent, 20–30 per cent and 30–100 per cent probabilities of receiving less than the stipulated amounts. Over 30 per cent unreliability is considered, as in previous papers, too risky for agriculture, since it implies a possibility of drought and crop failure in 30 years out of 100 and there is always the chance that several failures may occur in sequence.

The areas of reliable rainfall in different regions on the same map are not strictly comparable, as 15 or 20 inches in the five months from April to August may be much less valuable than 15 or 20 inches in the three months from March to May. To counteract this discrepancy, however, a map has been drawn (Figure 3) to show the probability of receiving less than 25 inches in the five-month season: only at a few stations in the areas with a three-month season, around Fort Hall and on the coast south of Mombasa, were 25 inches found to be received at all frequently, and these are not shown on the map.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MERU
TEITA HILLS
MALINDI
APRIL–JUNE
MOMBASA
USAMBARA MTS.
LUSHOTO
TANGA
PEMBA
ZANZIBAR
SEASONAL RAINFALL IN KENYA
THE PROBABILITY OF RECEIVING LESS THAN 20 INCHES OF RAIN IN A SEASON
0–10%
10–20%
20–30%
30–100%
OR NUMBER OF YEARS IN 100 THE RAINFALL IS LIKELY TO BE LESS THAN 20 INCHES
BOUNDARIES OF REGIONS WITH DIFFERENT RAINFALL SEASONS
SCALE
0 20 40 60
MILES

Fig. 2

Figure 1 shows that along much of the coastal strip only between 10 and 20 years in a hundred is the rainfall from April to June likely to be less than 15 inches, but the probability of failure increases rapidly inland, leaving only a narrow belt of reliable rainfall, whilst the unreliable zone reaches the coast at intervals dividing the areas of dependable rainfall into isolated pockets. In very few areas at all are 20 inches likely to be received in these months (Figure 2).

East of the Rift Valley in the March–May season the maps show very clearly how limited are the areas with reliable rainfall. Even at the 15-inch level, the main areas with less than 30 per cent probability of failure are limited to the Highlands region N.E. from Nairobi to Mount Kenya and a little beyond. In Tanganyika, the mountain masses of Kilimanjaro, Meru and the Usambaras are isolated from one another by areas of low unreliable rain. It should be noticed that the wetter areas do not radiate equally from the summits of these highlands, but are mainly on their south-eastern slopes facing the prevailing winds. The Usambaras are wetter only towards the coast, showing that it is a fallacy always to expect increased rainfall as a direct result of greater altitude.

With the change to 20 inches in a season (Figure 2) the areas of reliable rainfall are restricted to a much narrower belt in the Kenya Highlands and to the three main mountain masses of north-east Tanganyika.

West of the Rift Valley the picture is more encouraging, with a five-month rainy season, and the farmer is much more likely to have enough rain to satisfy his crop requirements, although it must be remembered that over a period of five months more rainfall may be needed to offset losses due to evaporation.

The whole of the Highlands west of the Rift receives 15 inches (Figure 1) in its five-month season at least 90 per cent of the time (0–10 per cent probability of failure), although the probability of failure increases rapidly north-eastwards to the Northern Frontier District, south-eastwards to Narok, and also towards a dry zone along the shores of the Kavirondo Gulf and Lake Victoria, where offshore prevailing winds tend to drift developing storms towards Uganda. In contrast to the eastern region, however, the wetter slopes in this area tend to be those facing west. With the increase to 20-inch and 25-inch levels (Figures 2 and 3), the reliable areas are much reduced, though still of considerable extent. Whilst bridging the Rift Valley the highland area south of Solai and Thomson's Falls also remains noticeably reliable even at 25-inch level.

Summary

By mapping the reliability of different amounts of rainfall for the main rainy seasons of different regions, the contrast is emphasized between the area west of the Rift Valley with its longer rains and those areas with two distinct, but shorter rainy seasons. The maps show how important it is to consider the seasonal distribution of rainfall to find what proportion of the annual total, which in itself may be misleading, falls in a suitable period for crop growth. The marginal nature of the rainfall is illustrated by the rapid decrease in areas with reliable rainfall, as the expected levels of rainfall amount are increased.

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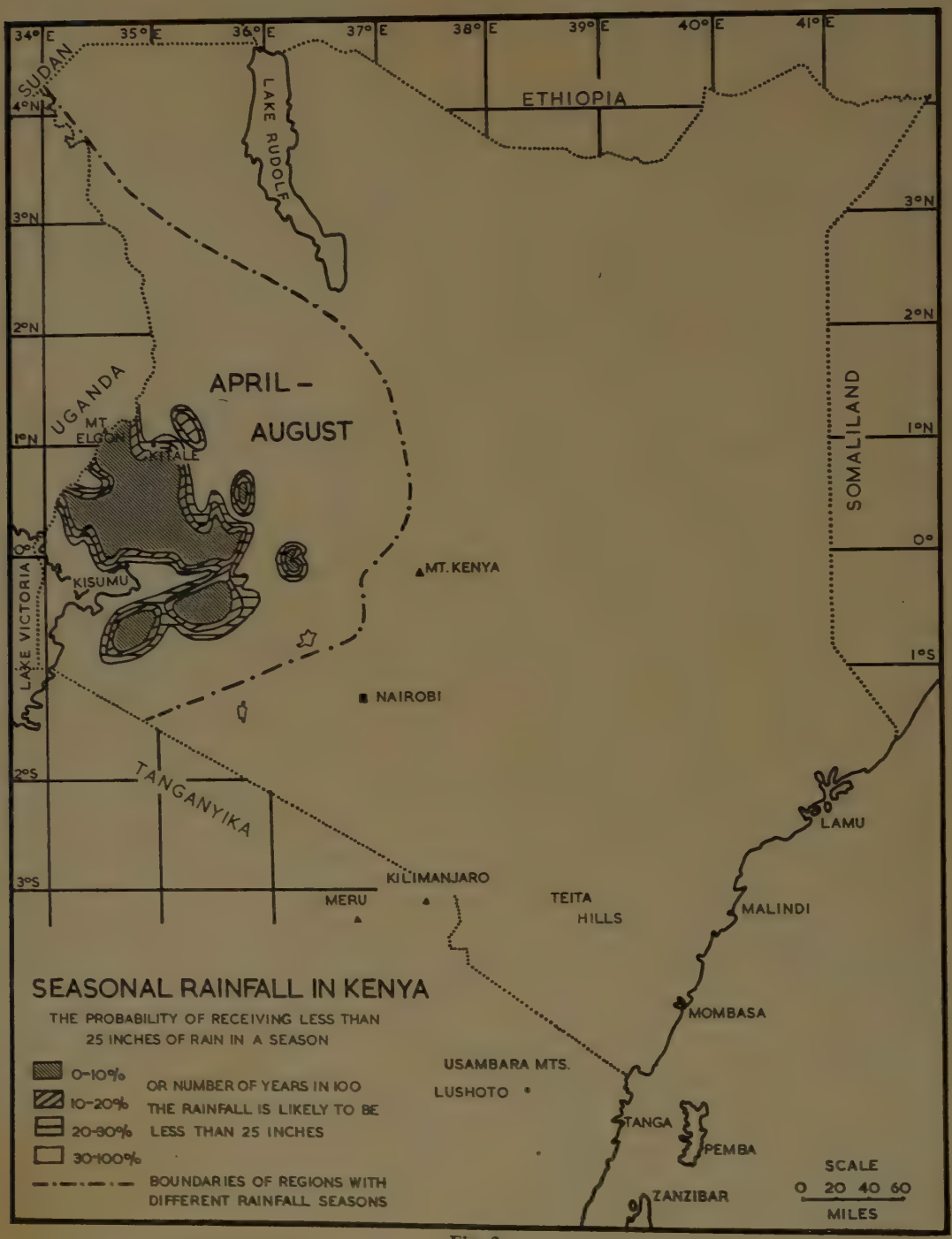
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SCALE
0 20 40 60
MILES

Fig. 3

ANTIBIOTICS AS DIETARY SUPPLEMENTS FOR POULTRY

By N'Kella Maeda, Department of Veterinary Services, Tanganyika

(*Received for publication 12th December, 1957*)

Experimental work involving the antibiotic response and benefit derived from addition of Aureomycin and Terramycin at certain levels to the normal chick diet has shown that these antibiotics promote early growth and reduce mortality in growing chicks. There are varying schools of thought regarding the way these antibiotics effect the response but the "Disease Control Theory" seems to be carrying the heaviest weight.

The Aurofac/Vitafac chick-feeding trial described here was conducted purely for interest during my long vacation and it aims at finding out whether the two antibiotics, supplementarily fed to growing chicks at the recommended rates, would give the claimed results; and it also aims at finding out which of the two gives better results. Besides the antibiotic response, the trial also aims at determining the cost of rearing 100 day-old chicks for eight weeks in simple home-made brooders so that when advising poultry farmers on methods of rearing chicks a first-hand, practical and local experience can be given.

Aurofac-2A contains 3.6 gm. Aureomycin hydrochloride per pound. Other ingredients are Aureomycin meal, diatomaceous earth, and oystershell meal. Feeding at the rate of 1 lb. of Aurofac per 100 lb. of chick mash is equivalent to feeding 1 gm. Aureomycin per 12,500 gm. chick mash. The recommended high level rate is 1 part per 20,000 parts.

Vitafac contains 0.7 gm. Terramycin, Vitamins A, D and B_{12}, cobalt and copper. Therefore, when fed at the rate of 1 lb. to 100 lb. chick mash, this is equivalent to 1 gm. Terramycin per 71,428 gm. chick mash, the recommended rate.

The chick mash used contained, in addition, "Vitamealo", i.e. vitamins A, B, D, E, K, minerals, and trace elements.

Procedure

Of 104 day-old chicks (52 W.L.H. and 52 R.I.R.) dispatched from Kigwaru Poultry Farm, Nairobi, by air on 6th August, 1957, 102 chicks (52 W.L.H. and 50 R.I.R.) arrived safely and two (R.I.R.) were received dead.

Housing.—Twenty-four hours after arrival and just before the trial started, the chicks were separated into three batches of 34 chicks and each batch placed in one of three boxes each measuring 3.5 ft. × 2.5 ft. × 1.1 ft. and having a run 7.5 ft. × 3.5 ft. × 1.75 ft. attached to it. These boxes served as brooders in which the chicks were reared throughout the period of eight weeks. The boxes were marked GR.1 (Aurofac), GR.2 (Vitafac), and GR.3 (Control) respectively, and each had a hurricane lamp burning to provide the necessary heat for four weeks.

Table I

Separation of the Chicks into Three Groups

GR.	*W.L.H.*	*R.I.R.*	*Total*
1 ..	18	16	34
2 ..	17	17	34
3 ..	17	17	34
Total ..	52	50	102

Feeding.—A 150-lb. bag of chick mash containing vitamealo was divided into three lots of 50 lb. each. Lot No. 1 had Aurofac thoroughly mixed in at the rate of 1 lb. Aurofac per 100 lb. chick mash. Lot No. 2 Vitafac at the rate of 1 lb. Vitafac per 100 lb. chick mash, and Lot No. 3 had nothing added. These were kept in three separate bags, and each batch of chicks were fed *ad lib* with the corresponding lot of feed in simple home-made food troughs. Similar mixtures were prepared every time fresh supplies of feed were purchased. Fresh water was available twice daily in appropriate-sized tins and an ample supply of green grass was also provided daily.

Management.—The boxes had sawdust filled to a depth of 2 in. from the floor. The sawdust was removed and a fresh lot placed every week. The chicks were reared on a clean ground well covered with grass and the boxes together with the run were moved to a new piece of land every three days.

Disease and Disease Control

Undiagnosed Disease.—On 27th August (exactly three weeks of age) one chick (W.L.H.) in GR.1 (Aurofac) was noticed showing nervous symptoms and paralysis of both legs. The chick was destroyed but post-mortem microscopic examination of intestinal and

coecal contents failed to give a clue as to what might have caused the condition. No similar case ever occurred thereafter.

Coccidiosis.—On 30th August (three weeks three days of age), blood was noticed in the droppings of a number of chicks in both GR.2 (Vitafac) and GR.3 (Control). Microscopic examination of the droppings confirmed coecal coccidiosis (*Eimeria tenella*). Treatment with 16 per cent Sulphamethazine solution in the drinking water on the same day immediately suppressed the infection without a single mortality. All the chicks, including those in GR.1 (Aurofac) underwent the treatment although no bloody diarrhoea had been noticed in GR.1. It is hard to explain why the outbreak occurred in GR.2 and GR.3 but not in GR.1, when all the groups were kept on the same field and under more or less the same conditions. Had GR.1 been left untreated perhaps the outbreak might or might not have occurred later on; but it was considered risky to leave them untreated. Whether Aurofac played a part in checking the outbreak is questionable. The chicks of all groups remained free from any disease during the remaining period of the two months.

Accidental Death.—One chick (W.L.H.) in GR.1 was accidentally killed on 10th September.

Observations

Throughout the trial period of eight weeks, it was difficult to notice with a naked eye any difference in size, feathering, or vitality in the chicks of the different groups.

The chicks of each batch were weighed collectively 24 hours after arrival, and weekly thereafter. Table II shows the differences in weight during the period.

The figures in Table II show that during the first three weeks there was no difference in weight of the chicks in the different groups, but a marked difference occurred during the fourth week. This difference was more marked in GR.2 (Vitafac), but in the end GR.1 (Aurofac) gave the best results with a difference of 2.7 oz. over GR.2 and 3.2 oz. over GR.3 (Control).

It appears, therefore, that both Aurofac and Vitafac at the recommended levels of feed do promote growth in growing chicks and that Aurofac gives better results. This growth response occurs within the fourth week of chick life.

Expressing the differences as percentages:—

Aurofac increases the growth rate by 17 per cent.

Vitafac increases the growth rate by 2.6 per cent.

Cost of Rearing 100 Day-old Chicks to the Age of Eight Weeks

	Sh.	*cts.*
Cost of 100 day-old chicks ..	220	00
Freight—by air Nairobi–Arusha	11	00
Cost of 600 lb. of chick mash ..	183	15
Cost of three boxes and runs ..	77	40
Cost of two tins of kerosene ..	25	20
Cost of three hurricane lamps ..	36	00
Cost of drugs	18	20
Total ..	570	95

The total cost of Sh. 570/95 is the bare minimum. It does not include labour and other minor items. It costs about Sh. 6 to raise one chick to the age of eight weeks, but, of course, much of the expense went into the purchase of the chicks.

Table II

Differences in Weight of Chicks in the Individual Groups and Average Weight/Chick

Group	No. of chicks			Average weight/chick		
	1	2	3	1	2	3
Date				*oz.*	*oz.*	*oz.*
7th August, 1957	34	34	34	1·9	1·9	1·9
14th August, 1957	34	34	34	3·3	3·3	3·3
21st August, 1957	34	34	34	5·2	5·2	5·2
28th August, 1957	33	34	34	6·6	6·6	6·6
4th September, 1957	33	34	34	8·2	8·5	8·0
11th September, 1957	32	34	34	13·2	13·2	12·7
18th September, 1957	32	34	34	18·0	17·4	16·0
25th September, 1957	32	34	34	19·0	18·8	17·4
2nd October, 1957	32	34	34	22·0	19·3	18·8

CONTROL OF INSECTS ATTACKING MAIZE ON THE COB IN CRIB STORES

By S. Kockum, Department of Maize and Produce Control, Kenya

(*Received for publication on 11th January, 1958*)

The climatic conditions in Kenya normally prevent maize from drying out sufficiently in the field to allow immediate shelling. At harvest time the husk is removed and the maize on the cobs is stored in cribs until dry enough for shelling and delivery. For this and various other reasons the harvested crop is often kept in this manner for six to eight months or even longer. During this storage time on the farm, before any control methods were introduced, ideal conditions existed for many pests to increase to large numbers causing considerable losses in weight and quality. In 1952 the Agricultural Department of Kenya made an investigation (unpublished) of losses in crib storage. Six untreated farm cribs in different districts were shelled out after four months, and six further untreated cribs were shelled out after six months. After correction for changes in moisture content the average weight loss during storage was found to be 9.6 per cent after four months and 23.1 per cent after six months. *Calandra oryzae* L. and *Sitotroga cerealella* Oliv. attack the growing crop, but build up mainly in the stores. From the cribs and stores these pests may spread to adjoining maize fields and to other grain crops such as wheat, barley and sorghum. The importance of reducing these enormous losses and preventing the pests from contaminating the growing crops has long been realized.

Experimental work on storage of cob maize was begun in 1952 at the Scott Agricultural Laboratories, Nairobi, and early in 1953 results had made it possible to issue recommendations for insecticidal treatments. Since then more than 9,000,000 cu. ft. of cob maize (representing 1,000,000 200-lb. bags) annually have been treated in Kenya, about 10 per cent of the total crop (European and African). Estimating a saving of 15 per cent in weight due to treatment, 150,000 bags, worth some £300,000, have been gained yearly by the farmers*.

Reports from some farms indicate that a break in cross-infestation from store to field may already have been achieved since *Calandra* has disappeared from their fields. However, when cob maize had to be stored for an extended period the insect population, though reduced, was still not defeated, and further experimentation has been undertaken to solve this problem.

Experimental Conditions

The experiments have been carried out in two cribs of the type used on Kenya farms, the internal size being 36 ft. long, 9 ft. wide and 9 ft. high from floor to eaves. The cribs are covered by corrugated iron roofs and have wooden floors raised from the ground on cedar poles. The sides are provided with open wire netting. For experimental purposes each crib is divided with wire netting through the centre lengthwise and by cross-divisions to provide 12 compartments, each able to hold 243 cu. ft. of maize on the cob. This makes it possible to use randomized experimental designs.

Experiment I

The results from the experiment carried out in 1952 showed that a good control of insects should be achieved by dusting the cobs as they were loaded into crib at harvest time with 0.4 per cent gamma BHC in a local diatomite powder, at the rate of 8 oz. per 9 cu. ft. of cobs. An analysis of the results indicated that 0.5 per cent of gamma BHC at the same rate (equivalent to 12.5 parts per million) should give complete control over a period of six months. This formula was recommended for practical use. Experiments carried out showed that this insecticide was almost entirely removed during the shelling operation.

Experiment II

When the cribs are exposed to wind, rain and sunshine over extended storage periods the insecticide deteriorates, leaving exposed cobs especially liable to insect attack. The object of the second experiment was to determine if this defect could be overcome by dusting the exposed cobs with a pyrethrum powder. Different strengths of gamma BHC and diatomite were also included in this trial.

*The guaranteed f.o.r. price for Grade II maize from 1956 year's crop was Sh. 39/98 per 200-lb. bag, without the bag.

Eight treatments in three replications made use of 24 compartments in two cribs as follows:—

Treatment 1.—Untreated control.

Treatment 2.—0.08 per cent gamma BHC in 4 oz. diatomite per 9 cu. ft. (=1 part per million BHC of grain).

Treatment 3.—0.28 per cent gamma BHC in 4 oz. diatomite per 9 cu. ft. (= 3.5 parts per million).

Treatment 4.—0.56 per cent gamma BHC in 4 oz. diatomite per 9 cu. ft. (= 7 parts per million).

Treatment 5.—0.04 per cent gamma BHC in 8 oz. diatomite per 9 cu. ft. (= 1 part per million). Outside dusted with pyrethrum powder after all maize had been loaded in.

Treatment 6.—Similar treatment to 5, but with second dusting of pyrethrum powder 10 weeks later.

Treatment 7.—Similar treatment to 5. Pyrethrum treated with oil soluble yellow.

Treatment 8.—Similar treatment to 6. Pyrethrum treated with oil soluble yellow.

Materials Used.—The diatomite powder came from Gilgil in Kenya and was finely ground. Moisture content of the powder was 13.4 per cent. The BHC used was Lindane (more than 99 per cent gamma BHC). Mixing with diatomite was carried out at our laboratory. The pyrethrum powder consisted of finely ground Kenya flowers with a pyrethrin content of 1.26 per cent Seil. The same pyrethrum powder was treated by V. A. Beckley with oil soluble yellow in the hope of making the pyrethrins longer lasting in light.

Thoroughly mixed cobs, after being separately treated, were placed in special wire-netting cages (cylindrical, about 2 ft. long and 1 ft. in diameter). These cages were placed at four levels (bottom, 3 ft., 6 ft., 9 ft.) and in two columns flush with the crib wall, and at the centre of each compartment.

The pyrethrum-dusted compartments received a dose of 1 lb. to 1¼ lb. pyrethrum per 100 sq. ft. applied with a Waldron dust gun, and for treatments 6 and 8 there was an interval of 10 weeks before the second dusting.

The cob maize was shelled after more than six months in the cribs. Two samples of about 1,000 kernels from each cage were divided into sound and damaged grain, counted and weighed. The figures obtained for percentage number of damaged grain were statistically treated and the analysis of variance gave the following information:—

No form of pyrethrum dusting had any effect. The lowest dosage of gamma BHC had significant effect only inside the bulk. The lowest dosage was not as effective as the two higher dosages of BHC. The highest dosage was most effective of the three on the outside, but inside the bulk no difference was shown between the two highest rates of application. There was no significant difference between the two dosage rates of diatomite.

Experiment III

As dusting with pyrethrum had failed to protect the outer surface from insect attack, it was thought that such protection might be achieved by some physical or combination of physical and chemical means.

On some European farms cribs known as Argentine cribs are used. These are provided with walls of maize stalks. One type of native crib has walls made from grass thatch or reeds, others of a wickerwork of thin wooden branches which often are mud plastered. Obviously all types of construction could not be included in one experiment. It was decided to use the two cribs to try out six treatments with four replications. The sample cages in four layers were placed as in Experiment II, in two columns, flush with the outside wall, and centrally inside the compartments. The experiment became factorial with five factors: cribs, block (each side of crib), treatments, layers and position (outside and inside).

In order to emphasize the difference between outside and inside damage all cobs were treated with 8 oz. per 9 cu. ft. of diatomite dust containing 0.06 per cent gamma BHC (1.5 parts per million of grain when 200 lb. of maize is shelled out from 9 cu. ft. of cobs). Only the four compartments used as controls were not dusted.

Treatments were:—

1. Untreated control, wire-netting wall, no dust.
2. Wire-netting wall, BHC-diatomite dusted cobs.
3. Napier grass-covered wall, BHC-diatomite dusted cobs.
4. Grass thatch-covered wall, BHC-diatomite dusted cobs.

5. Hessian-covered wall, BHC-diatomite dusted cobs.

6. Hessian-covered wall, the hessian treated with BHC resin, BHC-diatomite dusted cobs.

Napier grass was used as maize stalks were not available at the time. The Napier grass stalks were thick and when they were held against the wire netting by pressure of the cobs the wall became similar to that of an Argentine crib, or of a reed (papyrus) crib, as used by the Luo tribe in the vicinity of Lake Victoria.

The grass thatch was made by grass bundles tied together with string, overlying each other in rows and fastened to the outside of the wire netting. This type of wall simulates the store walls used by the Kamba tribe.

The hessian cloth was placed on the inside of the wire netting. In the sixth treatment the hessian was sprayed, after the crib was filled, with gamma BHC dissolved in kerosene with coumarone resin (Coumarone Indene Resin, Grade C.469, British Resin Products Limited, 21, James Square, London, W.C.1) added amounting to 10 per cent of the weight of the insecticide. The gamma BHC used in the spray, plus that small amount used in the dust (1.5 parts per million), was equivalent to the total amount used in the previously recommended dust method (12.5 parts per million).

The application was 40 g. of gamma BHC and 4 g. of coumarone in 1 litre of kerosene per 100 sq. ft. of hessian. The resin was added with the intention of slowing down the rate of evaporation of BHC.

In Experiment I significant interaction occurred only in the central sample cages which were flush with compartment walls shared by other treatments In the following experiments only sampling cages flush with the outer walls (outside) and those in the centre of compartments (inside) were used.

However, in Experiment III interaction between certain neighbouring compartments was strongly felt in both inner and outer cages. In future experiments of this kind the compartments will have to be separated either by a free passage or by a solid wall. Shelling took place after 10 months. Gamma BHC (0.06 per cent in diatomite at 8 oz. per 9 cu. ft. or 1.5 parts per million of shelled maize) was not shown to have any significant effect after 10 months of crib storage. No significant difference could be detected between any of the bare wire-netting walled compartments and those covered with Napier grass, grass thatch or untreated hessian. The only treatment significantly different and very outstandingly so was where the hessian walls were treated with BHC plus resin. An almost complete protection against insect damage was obtained both outside and inside in the three upper layers. In the bottom layer there was some damage due to the insects coming in from neighbouring compartments and mainly from the untreated control compartments. It was from these treated hessian compartments that interaction was strongly felt in neighbouring compartments. To illustrate the results average figures of percentage number damaged grain in layer 3 ft. and 6 ft. are given in Table 1. The range indicates the high degree of interaction.

TABLE 1—AVERAGE PERCENTAGE DAMAGED GRAIN (NUMBER) IN THE LAYER 3 FT. AND 6 FT.

	Inside samples	Outside samples	Average	Range
Untreated, bare	74.6	91.6	83.1	46.5—99.3
Bare, 1.5 p.p.m. gamma BHC	60.2	85.1	72.6	9.6—97.8
Napier grass, 1.5 p.p.m. gamma BHC	59.1	88.4	73.7	15.9—93.7
Grass thatch, 1.5 p.p.m. gamma BHC ..	37.3	54.4	51.3	1.4—98.9
Hessian, 1.5 p.p.m. gamma BHC	33.7	62.8	48.3	0.7—97.9
Treated hessian, 1.5 p.p.m. gamma BHC	1.5	1.5	1.5	0.30

EXPERIMENT IV

When the extremely promising experimental results with treated hessian crib walls were obtained, it was decided to go ahead with a full-scale test. Instead of using both cribs for an experiment of similar statistical design, it was felt that one complete crib should be treated with hessian cloth sprayed with BHC resin. The other crib was to have in two compartments untreated cob maize and in another two maize treated with 0.5 per cent gamma BHC in diatomite at a rate of 8 oz. per 9 cu. ft. (1953 recommendations). Four compartments were to be used for a test of half the amount of BHC resin sprayed onto hessian walls, and the cobs dusted with 4 oz. of 0.12 per cent gamma BHC per 9 cu. ft. Empty compartments were to be left between each of these treatments.

An analysis of variance of the figures from the crib with fully treated hessian shows no significant difference between outside and inside columns, and no significant difference between layers, nor any significance between the groups of samples within layers.

With an initial damage at the beginning of this experiment of 1.12 per cent ±0.95 (S.E.) and a standard error of ± 1.35 for the sample values it cannot be established that any damage has taken place during the thirteen-month storage except possibly a small amount of damage at some points at the top and bottom of the crib.

The treatment of hessian with a lower dose, and the treatment with 0.5 per cent gamma BHC dust having ordinary walls, gave considerable protection yet not satisfactory protection for such a long storage period.

TABLE 2—PERCENTAGE NUMBER DAMAGED GRAIN

Treatment	*Outside Average*		*Inside Average*		*Whole Crib*
*	**	*Range*	***	*Range*	*Average*
1.	2.5	1.1— 4.8	1.8	0.4— 3.5	2.2
2.	29.0	4.8—88.9	11.5	4.7—24.0	20.3
3.	31.8	2.2—92.0	5.7	2.9—17.6	20.2
4.	95.9	80.8—99.8	86.0	70.1—99.5	91.0

*1. Hessian walls treated with 40 g. gamma BHC plus 4 g. coumarone resin in 1 litre kerosene per 100 sq. ft. Cobs dusted with 0.06 per cent gamma BHC at 8 oz. per 9 cu. ft.

2. Hessian walls treated with 20 g. gamma BHC plus 2 g. coumarone resin in 1 litre kerosene per 100 sq. ft. Cobs dusted with 0.12 per cent BHC at 4 oz. per 9 cu. ft.

3. Ordinary wire-netting walls. Cobs dusted with 0.5 per cent gamma BHC at 8 oz. per 9 cu. ft.

4. Ordinary wire-netting walls. Cobs untreated.

** *Outside.*—Cages placed flush with crib wall and at top level (9′) inside crib.

*** *Inside.*—Cages placed inside bulk at floor level and at 3′ and 6′ levels.

DISCUSSION

When, as a result of our first crib experiment, dusting cob maize with 0.5 per cent gamma BHC in diatomite at a rate of 8 oz. per 9 cu. ft. came into general use among European farmers in the Kenya Highlands, it was found that a few farmers experienced partial failures through uneven application of dust. That an even distribution of BHC dust is necessary has been shown in a bag experiment (unpublished). Some farmers complained about the dust nuisance created at shelling. In our second trial it was found that the diluent, diatomite, could be reduced by half, but in such a case extra careful supervision of application is needed during a very busy time on a farm. Also when crib storage was continued for more than six months the grain was attacked by insects on exposed surface layers. Though in the last trial it was shown that this damage during a full year does not exceed that occurring in an untreated crib after a few months, the main source for cross-infestation of new crops in the field remains.

In the last two experiments a completely new method of storing maize on the cob in cribs has been devised. By providing the crib with a thin hessian cover which is sprayed with a strong BHC plus coumarone resin solution, and by considerably reducing the strength of actual insecticidal dust applied to the cobs, it has been demonstrated that maize can be stored for over a year in almost perfect condition. It is possible that the presence of a slowly evaporating gas barrier around the treated grain prevents the insecticidal dust from deteriorating as long as the gas barrier remains. The high degree of interaction experienced in the third experiment indicates that the extra careful distribution of dust can be relaxed, and it is believed the diluent can be reduced if preferred in this method of crib storage. Exposed grain in an open crib becomes discoloured yellowish-brown. This does not happen to maize in a crib with covered walls. Determinations of moisture content at shelling time did not reveal any significant differences relevant to different treatments. In all treatments the grain had a slightly increasing moisture content from top to bottom. No moulding took place, which indicates that the grain was not in an atmosphere of a high relative humidity for a long period at any time during the storage. This indicates that a light cover of the crib walls, as used, does not interfere with the normal drying conditions in the crib.

The cost of this new method compared with that previously recommended is increased mainly by the expense of hessian, which at the present prices in Kenya will amount to an additional 30 cents (East African currency) per 200 lb. bag of maize. This cost will be spread over more than one season. The extra outlay for kerosene, coumarone and labour is small. The gain in preventing cross infestation to the fields of maize and other crops and the extra protection afforded to the grain in the cribs will certainly offset this extra cost. Further, experimentation will be undertaken to find if the same results will be achieved by using maize stalks instead of hessian and thus reduce the cost of treatment.

The use of resin has to be further investigated.

Summary

Experiments aiming at protection of maize on the cob against insect damage in cribs are described. Details of the cribs, the layout of these experiments and material used are given. The main results are:—

1. That while excellent insect control over a period of six months is achieved when dusting maize on the cob with 0.5 per cent gamma BHC in cribs with ordinary wire-netting walls, this control becomes unsatisfactory over a period of 13 months.

2. That by reducing the diluent from 8 oz. to 4 oz. per 9 cu. ft. of cobs and doubling the BHC content no difference in the protection was observed.

3. That dusting the exposed surface of the maize with pure pyrethrum powder of 1.26 per cent pyrethrin content, as carried out, did not result in reduced damage.

4. That different types of crib walls made from wire netting, Napier grass, grass thatch and ordinary hessian cloth showed no difference in protecting the grain from insect damage. The grain becomes discoloured on exposed sides of open wire-netting cribs. This discoloration does not occur in cribs with walls of the denser material.

5. That virtually complete protection for 13 months was given in maize dusted with 0.06 per cent gamma BHC at the rate of 8 oz. per 9 cu. ft. and by surrounding the crib with a wall of hessian cloth treated with 40 g. gamma BHC plus 4 g. coumarone in one litre of kerosene per 100 sq. ft. The treatment uses an amount of BHC equivalent to that used in the dust treatment of 0.5 per cent gamma BHC in a crib with ordinary wire-netting walls.

Acknowledgments

The experiments were directed by the Pest Control Committee and made possible by provision of the Maize and Produce Control. They were carried out in Nairobi at the Entomological Section of the Scott Agricultural Laboratories of the Department of Agriculture. Thanks are due specially to Dr. R. Le Pelley, Senior Entomologist, for his interest and help, and to the African staff for good work in counting and weighing the samples.

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PRODUCTION OF KILN-DRIED COPRA IN THE TANGA PROVINCE OF TANGANYIKA

By A. H. B. Childs, Department of Agriculture, Tanganyika

(*Received for publication on 17th October, 1957*)

At present there is a demand for low-grade copra for soap-making in the coastal districts of the Tanga Province, but the demand will probably decrease as the synthetic washing powders and fluids become more popular and cheaper to import. The trade will then demand clean copra for the manufacture of edible oils, and kiln-drying seems to be the only way in which the quality can be raised to meet this demand.

Most of the copra produced at the present time is acid, evil-smelling, off-colour and under-dried. Some of it is neutralized, deodorized and decolourized for use in making edible oil, but the process is so costly that low-grade copra would be unacceptable if high-grade material was available.

Copra producers admit that there is more profit in kiln-drying than in sun-drying, but they maintain that they are unable to kiln-dry because they cannot wait for the processing period before receiving their cash. Consequently they harvest unripe nuts, sun-dry them for one or two days and have to be content with a low price for an extremely low-grade product. Many of the producers live in a state of permanent indebtedness, and rely on advances to cover general expenses and those of social and religious functions. Thus they are not able to store or properly process their nuts, as the traders from whom they have borrowed money are pressing for payment. As soon as the crop becomes saleable, no matter in what condition, it is harvested and sold as quickly as possible. Other producers harvest immature nuts because they are likely to be stolen if left to mature on the tree: predial larceny is a major problem in the coastal districts.

Sun-dried copra is usually sold to traders, who pay whatever price they think fit, and the copra brought to the mills by them is sold on moisture content as estimated by the purchaser. On the other hand producers of kiln-dried copra are assured of getting a fair price, as their product is sold through a Copra Society, which inspects the copra at the mill before sale and arranges a price which is considerably above that for low-quality sun-dried copra. Millers are willing to pay the higher price for the kiln-dried product, as it is less expensive to turn the oil from clean copra into edible oil. If the production of kiln-dried copra was higher than it is an even bigger premium could be paid, because the quantities offered at present are insignificant, and clean copra is often mixed with low-grade copra in order to make up a sufficient quantity for milling.

Some of the larger producers are now making kiln-dried copra at a good profit, and smaller producers are being encouraged to use the kilns of their neighbours, who are usually quite agreeable to this. But the idea is spreading only slowly, partly because the time between harvest and sale is relatively long, and also because the difference in price is said to be insufficient. Further, the small producer claims that he gets more copra per 1,000 nuts if he sun-dries, but while this is true it is more than counteracted by the lower price he receives for his copra. The difference in profit between kiln-drying and sun-drying is at least Sh. 21/50 per 1,000 nuts, and it may be more if the sun-dried copra is of exceptionally poor quality.

Profit from Kiln-drying

Three types of kilns are used in the Province, and to date 45 of these have been built. They are cheap to construct, and they produce a reasonably high-grade copra with a Free Fatty Acid content and moisture content much lower than sun-dried copra. Samples of sun-dried copra and copra from these kilns were sent to the Government Chemist for analysis, and the results in Table I show the benefit from kiln-drying.

Table I

Sample	*% moisture*	*% F.F.A.*
Kiln-dried mature nuts	6.5	1.2
Kiln-dried immature nuts	8.1	2.3
Sun-dried immature nuts	13.1	15.5
Sun-dried and stored one month	7.6	6.3

The kilns producing this type of copra can be constructed for from Sh. 500 to Sh. 700, depending on the type and the local price of building materials. As each kiln processes 2,000 to 3,000 nuts at a time, the gross return on each processing is between Sh. 43 and Sh. 64/50 more than would have been received had the same nuts been sun-dried, so the kiln pays for itself in ten or 12 processings.

Kiln Type No. 1

This kiln, the plan of which is shown in the diagram, is simple in design and operation, consisting of a small building divided into two sections, with a platform of expanded metal forming the drying trays. The walls are constructed of mud and wattle and the roof is covered with coconut leaves. The kiln has a capacity of 3,000 nuts, which take four days to process. The cost to build is approximately Sh. 500. Only coconut shells are used for fuel, as it gives off very little smoke compared with husk and is much hotter. The sheels are laid on the ground as shown in 4 of the diagram, in two rows with one row on top, each shell being fitted into the cavity of the next. The line of shells will burn for eight hours without replenishment.

Operational Programme

First Day.—1,500 nuts are husked, the shells split and placed on the first tray: they should not be husked the day before processing, as cracked nuts will begin to rot immediately. The halved nuts are placed on the tray with the cut surface downwards, and only three layers of nuts are used. The first layer is spaced so that the heat from the fire below can penetrate to the second and third layers: this spacing of nuts is most important, and if the first layer is spaced too closely together all the heat will be retained in it and the second and third layers will remain wet. The shell fuel in the heating chamber is now lit at one end, and the heat should be sufficient to reduce the moisture in the kernel from 50 per cent to 20 per cent in the first eight hours.

Second Day.—Firing is continued all day and all night.

Third Day.—The nuts are allowed to cool, the shells are removed, and the kernels are placed on the second tray with their cut surfaces uppermost. 1,500 fresh nuts are dehusked, split and placed on the first tray; the fire is then relit.

Fourth Day.—Firing is continued all day and all night.

Fifth Day.—The kernels on the second tray, which are now copra, are removed and stored. The nuts on the other tray are shelled and placed on the second tray and the process is continued as before.

The advantage in having two trays is that there is room for deshelling from one tray to another.

The copra produced in this way has a moisture content of six per cent to eight per cent and a slight smoky appearance. The latter is not detrimental to quality, and, in fact, it is said to prevent fungus attack.

All measurements of the kiln are shown on the diagram. The main points to remember are that the eaves of the roof should be brought well below the top of the walls of the heating chamber, and that the heating chamber wall should be carried at least one foot above the level of the tray. These precautions prevent the nuts cooling while they are being processed and make a big difference to the final product.

Kiln Type No. 2

This is a modification of Type No. 1, and was introduced two years after 40 kilns of Type No. 1 had been in operation. The advantage of the modification is that Type No. 2 kiln can produce a similar grade copra in 1½ days compared to the four days required by No. 1 type. The No. 2 kiln takes 2,000 nuts, 1,000 less than No. 1, and costs approximately the same to build. The cost of conversion of No. 1 to No. 2 is Sh. 30 to Sh. 50.

The building is externally the same, but it differs internally in that the tray surface is 3 ft. by 11 ft. on each side, instead of 6 ft. by 12 ft., and the nuts are placed in a box, with sides 3 ft. high, on top of the tray. The top of the box is covered with coconut leaves, with two outlets, 1 ft. by 1 ft., for moisture to escape.

The distance between the bottom of the tray and the fire has been increased from 6 ft. to 7½ ft., and the fire is placed in pits instead of on the level floor, as shown at 6 and 7 on the diagram. It was found that the fire keeps its heat better in these pits and does not die out so quickly.

The heat spreader, which is shown at 6 and 7 on the plan, is hung 1 foot below the bottom of the tray, and extends its full length. It consists of a strip of metal 1 ft. wide and curved downwards: this device is essential, as it ensures that there is no overheating of the bottom layer of nuts. The walls of the heating chamber are reduced from a width of 6 ft. at the bottom of the chamber to 3 ft. at the bottom of the tray. This is done by driving poles into the wall of the chamber halfway up its height, forcing the other end of the pole through the expanded metal, and tying it in position. The deflecting wall so formed is lathed and plastered with mud; it stands up well to the heat which it deflects.

The box on top of the tray has no bottom, and the sides are made of a framework of poles joined together with laths. After it is placed in position on top of the deflecting wall it is plastered with mud in the same way as the wall, thus joining the wall and the box into one unit.

Only coconut shells are used as fuel, and they are placed in the pits two abreast, but not with an additional one on top as was done in Type No. 1, as too much heat is generated if three rows of shells are used. This fire will burn for six hours without replenishment.

Operational Programme

First Day, Afternoon.—Husk and split 2,000 nuts and place them in the boxes, the bottom layer having the cut surface downwards, leaving plenty of space between the shells to allow the heat to penetrate to the layers above. When the nuts are in position cover the box with coconut leaves, leaving two vent holes 1 ft. by 1 ft. Light the fire at 4 p.m.

Second Day.—At 7 a.m. cool off the kiln and deshell the nuts. At 9 a.m. replace the nuts and relight the fire.

Third Day.—Cool off the kiln at 7 a.m. and remove the copra: prepare 2,000 nuts for processing and light the fire at 4 p.m.

The total firing time is 39 hours.

This kiln produces copra similar to that made in Type No. 1, but it is a little more smoky. If stored for two weeks it fetches the highest price at the mills, with a moisture content of six per cent to eight per cent.

KILN TYPE NO. 3

This type of kiln is worked on a different system, in that the heat is carried in flues and is not applied direct to the nuts. The copra produced is quite white, with a moisture content of five per cent to six per cent, and it can be sold direct to the mill for the highest price. The Free Fatty Acid content is low and it is very suitable for the manufacture of edible oil.

The kiln has a capacity of 3,000 nuts, 1,500 being ready every day. The cost of construction is Sh. 600 to Sh. 700 if old tar barrels are used as flues, but the cost is considerably higher if oil drums are used. It is best to build the walls of sun-dried bricks, which can be of any convenient size and are laid according to the diagram, ventilators being placed at the foot of the walls as indicated at 9 on the plan. The ceiling of the heating chamber is made of mud and wattle, with three ventilators, 1 ft. by 1 ft. spaced as shown at 10 on the plan. The roof over the ceiling should be of iron or aluminium, as there is a great danger of sparks from the chimney.

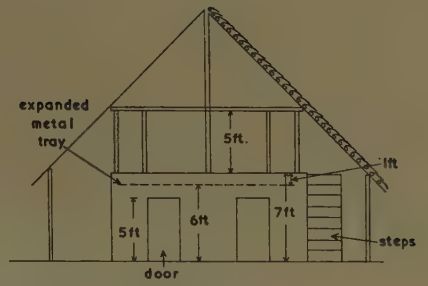
The main door and the small doors on the ventilators are made of wood frames with metal panels. The fire box is made of mud brick with a metal top, which can be an opened-up tar barrel, while the flues and chimney consist of tar barrels which have been welded together, six being sufficient for the flues and four for the chimney.

The trays consist of 1½-inch mesh expanded metal, and are 4 ft. wide. They extend along one side and the end wall of the heating chamber, and there are four trays, spaced as shown at 12 and 14 on the plan. The supports for the trays must be of metal because of the heat generated in the flue, which comes in close contact with them. The cheapest material for these supports is discarded light rail which can sometimes be obtained from sisal estates. The first cross-support for the trays must also be of metal, but the second, third and fourth can be mangrove poles, which withstand the heat.

Husk is the main fuel, but small amounts of shell are added to keep the flame bright. Shell alone is unsuitable, as it makes a very hot fire and will burn out the flues quickly. The furnace must be stoked continuously to maintain the heat.

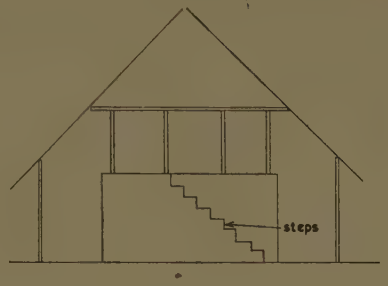
KILN TYPE No. 1

1



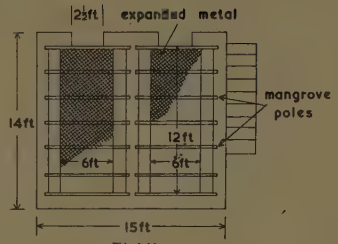
FRONT VIEW

2



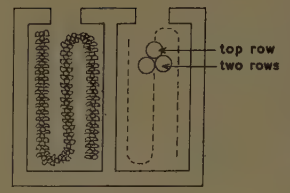
SIDE VIEW

3



PLAN

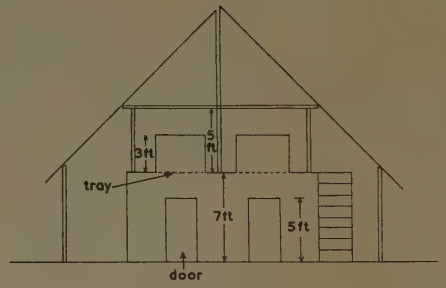
4



FUEL PLAN

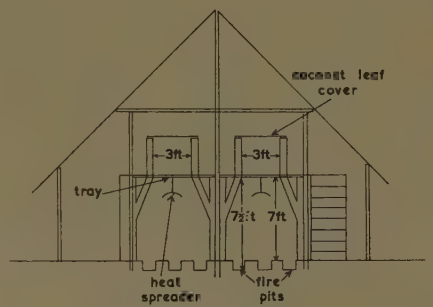
KILN TYPE No. 2

5



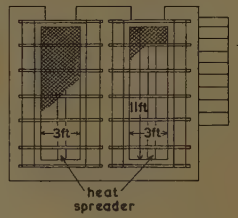
FRONT VIEW

6



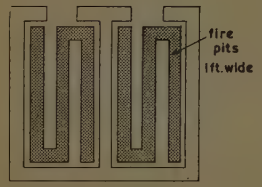
CROSS SECTIONAL FRONT VIEW

7



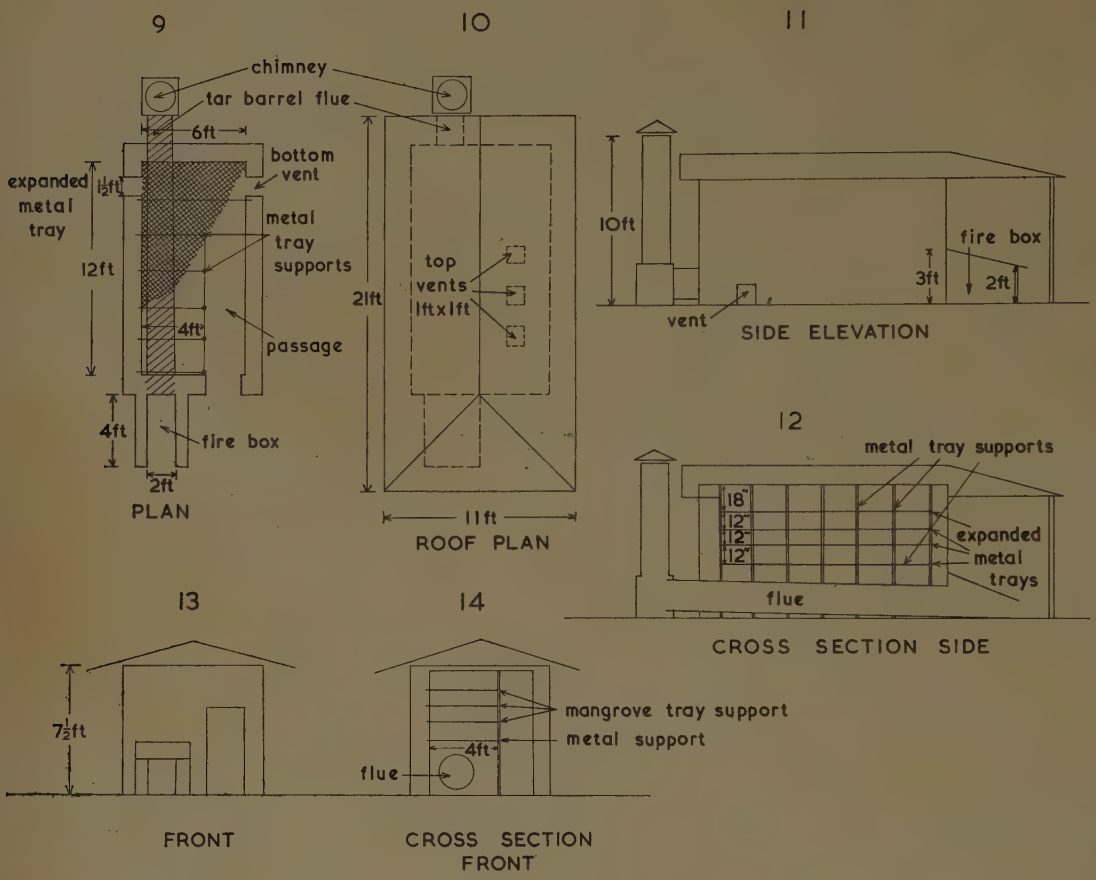
PLAN

8



FIRE PIT PLAN

KILN TYPE No. 3



Operational Programme

First Day, 8 *a.m.*—1,500 nuts are husked, split and placed on the two bottom shelves, with the cut surface downwards. The fire is kept burning continuously.

Second Day, 7 *a.m.*—The kiln is cooled off and the nuts are transferred to the top two shelves. The two lower shelves are now filled with fresh nuts and the fire is relit.

Third Day, 7 *a.m.*—The kiln is cooled down again, the nuts on the two top shelves are removed and stored, those on the lower shelves are transferred to the top shelves and fresh nuts are placed on the bottom shelves. The fire is relit.

The ventilators in the ceiling should be kept open sufficiently to allow moisture to escape, and those at the bottom of the walls should be open only very slightly when drying is taking place but should be fully open when the kiln is being cooled off. The operational temperature is 140° F., and this must be maintained. For maximum efficiency the kiln should be operated continuously, as once it is cold it takes some hours to heat up to operational temperature.

This kiln can also be used for drying fish and cassava.

SUMMARY

The quality of sun-dried copra in the Tanga Province of Tanganyika is so low that most of it can only be used for soap-making. Kiln-dried copra fetches a higher price for the manufacture of edible oil, and the industry would benefit greatly if more copra kilns were used. Plans are given for three types of inexpensive copra kilns, and the method of operation is described. One of these kilns could be used for drying fish or cassava.

AVERAGE ESTIMATES OF DIGESTIBLE CRUDE PROTEIN IN KENYA FEEDING STUFFS

By H. W. Dougall, the Grassland Research Station, Department of Agriculture, Kenya

(*Received for publication on 7th November, 1957*)

The digestibility of the proximate constituents of animal feeding stuffs, as defined by the difference between the ingested component and the faecal component, is determined as a rule only from animal digestibility experiments. In the case of crude protein (c.p.), however, it is well known that if a feed is treated with pepsin and hydrochloric acid under specified conditions (Wedemeyer, 1899), and the insoluble protein that remains is determined, an estimate of the "digestible" crude protein contained in the feed can be obtained by difference, viz. % c.p. in feed − % c.p. in residue = % c.p. digested. Woodman, Blunt and Stewart (1926) found that Wedemeyer's artificial digestion tends to give protein digestibility values for hays, silages and oil cakes that are higher than the corresponding values obtained by digestibility trials with sheep. They ascribed the differences between the results obtained by artificial digestion and those obtained by ruminant digestion to the presence of metabolic nitrogenous material in the faeces of the sheep. When the sheep were consuming a pasture grass diet, Woodman and his colleagues found only slight differences between the artificial and the ruminant digestion, and they concluded that only small amounts of metabolic nitrogenous material were present in the faeces of the sheep.

It is reasonable to suppose that the amount of digestible crude protein contained in a feeding stuff should be estimated with greater reality "in vivo" than "in vitro", but where facilities for the former technique are not available, Wedemeyer's artificial digestion until very recently has provided the only convenient alternative. Now, as a result of making a synthesis of world data appertaining to animal digestibility experiments, Glover, Duthie and French (1957) have derived a simple equation in which they have connected the digestibility of the crude protein contained in the dry matter of a single or a mixed feed to the total crude protein (c.p.) contained in that feed. Their equation may be rewritten in the form: digestible protein (dig. P) = c.p. (70 log. c.p. − 15) ÷ 100, and it is seen that an average estimate of the digestible crude protein contained in a feed can be calculated once the crude protein content of that feed has been determined. Glover and French (1957) have derived a second equation which may be used for feeds in which crude fibre (c.f.)/crude protein ratios are abnormal. This equation may be rewritten in the form: dig. P. = c.p. (5 + 60 log. c.p. − 0.33 c.f.) ÷ 100, and from it an average estimate of the digestible crude protein contained in a feed can be calculated once the crude protein and the crude fibre content of the feed have been determined.

In this laboratory the artificial digestion technique of Wedemeyer has been used for a number of years as the only method available for obtaining an estimate of the digestible crude protein contained in a wide range of Kenya feeding stuffs. Fortunately, crude fibre as well as crude protein had been determined on these feeds and, when the Glover and French equation appeared, it at once became possible to arrive at average estimates of the digestible crude protein contained in the same Kenya feeds simply by calculation.

The objects of this paper are (i) to present respectively "Wedemeyer" estimates and "Glover and French" estimates of digestible crude protein in relation to the crude protein contained in the same Kenya feeding stuffs, and (ii) to discuss the relative practical value of each of these two ways of deriving average estimates of digestible crude protein in feeding stuffs generally.

The "Wedemeyer" Relationship Between Digestible Crude Protein and Crude Protein

Examination of the results of 75 pepsin-HCl determinations carried out in this laboratory with Kenya feeding stuffs ranging in the crude protein content of their dry matter from just over 1 per cent to over 40 per cent, and in their crude fibre content from just over 3 per cent to 43 per cent shows that the percentage digestible crude protein (dig. P.) is related directly and highly significantly to the percentage crude protein (c.p.). This relationship (Fig. 1) is expressed by the rectilinear

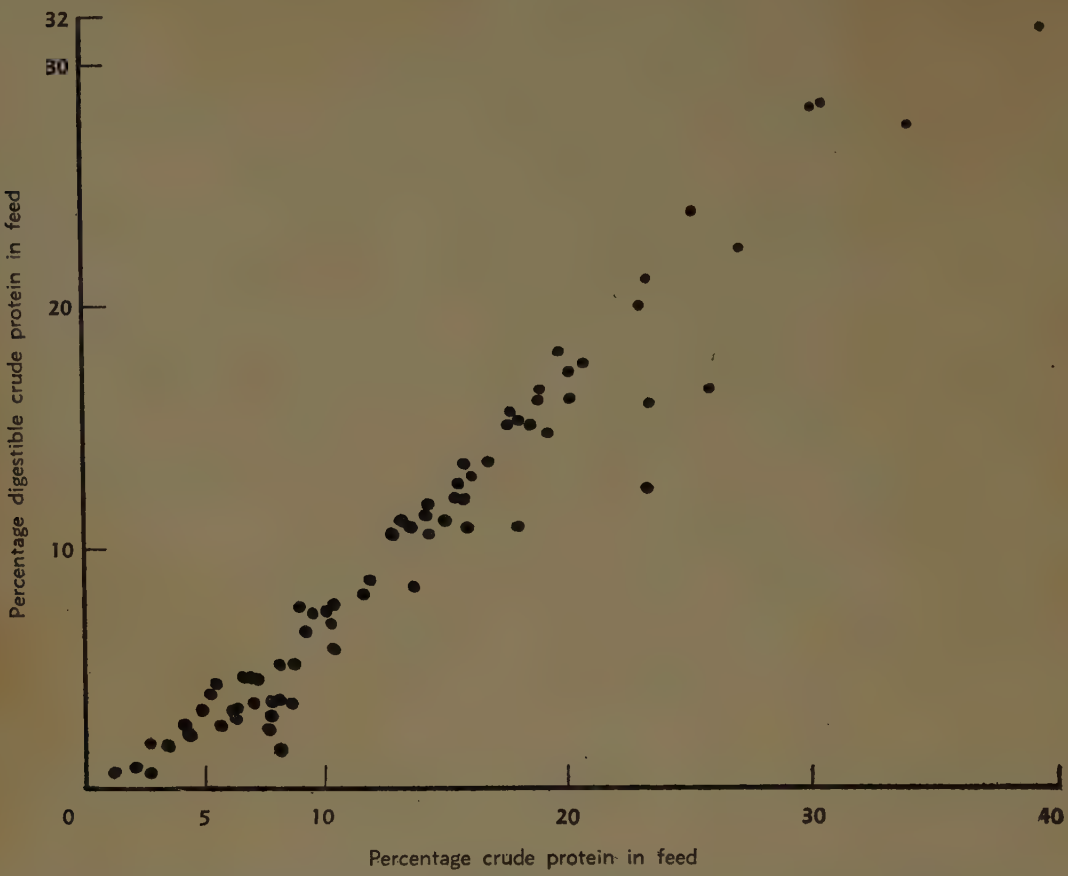


Fig. 1.—The relationship between crude protein and digestible crude protein (Wedemeyer) in Kenya feeding stuffs

equation: dig. P. = 0.94 c.p. − 2.51 ($1-r^2$ = 0.04) - - - (1). Since crude fibre/crude protein ratios varied in the Kenya feeding stuffs between 15/1 and 0.09/1, it was thought that the possibility of correcting for the former constituent might be worth investigating. However, when the crude fibre content of the feeds was taken into account in a multiple regression, the effect of crude fibre was found to be non significant (dig. P = 0.96 c.p. + 0.02 c.f. − 3.16), and so, in fact, no improvement on the rectilinear equation was achieved.

Crude fibre is apparently not important in Wedemeyer's artificial digestions, but on the other hand it is well known that it is very important in animal digestibility experiments. It therefore seemed appropriate at this stage to apply to the Kenya data the equation of Glover and French which is designed to take crude fibre into account.

The "Glover and French" Relationship Between Digestible Crude Protein and Crude Protein

The Glover and French equation from which average estimates of digestible crude protein can be made in circumstances where crude fibre/crude protein relationships are abnormal is, as already mentioned, dig. P = c.p. (5 + 60 log. c.p. − 0.33 c.f.) ÷ 100 - - - (2) and when this equation is applied to the relevant data for the Kenya feeding stuffs, the result is as shown graphically in Fig. 2. It is noteworthy that this equation produces estimates which have less scatter than those of the direct Wedemeyer determinations.

Discussion

The relative practical value of the two equations cannot be determined from the Kenya data because no animal digestibility experiments could be conducted on these

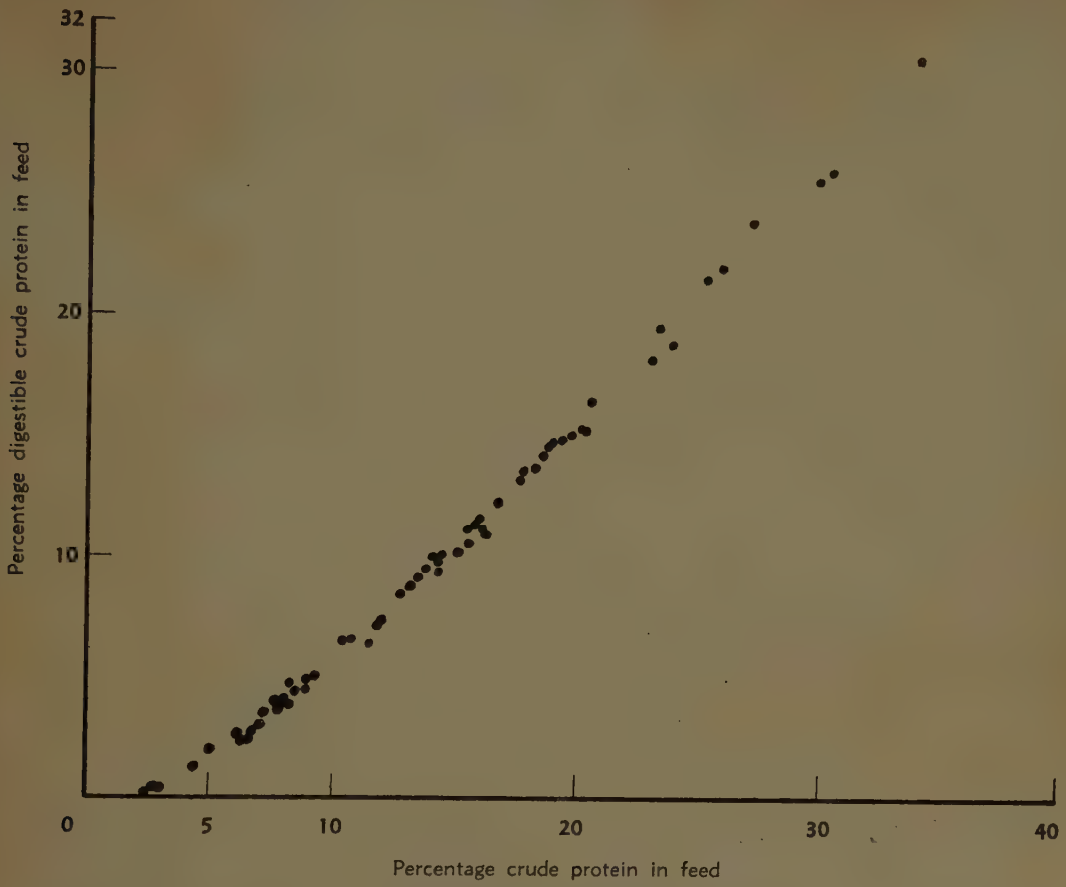
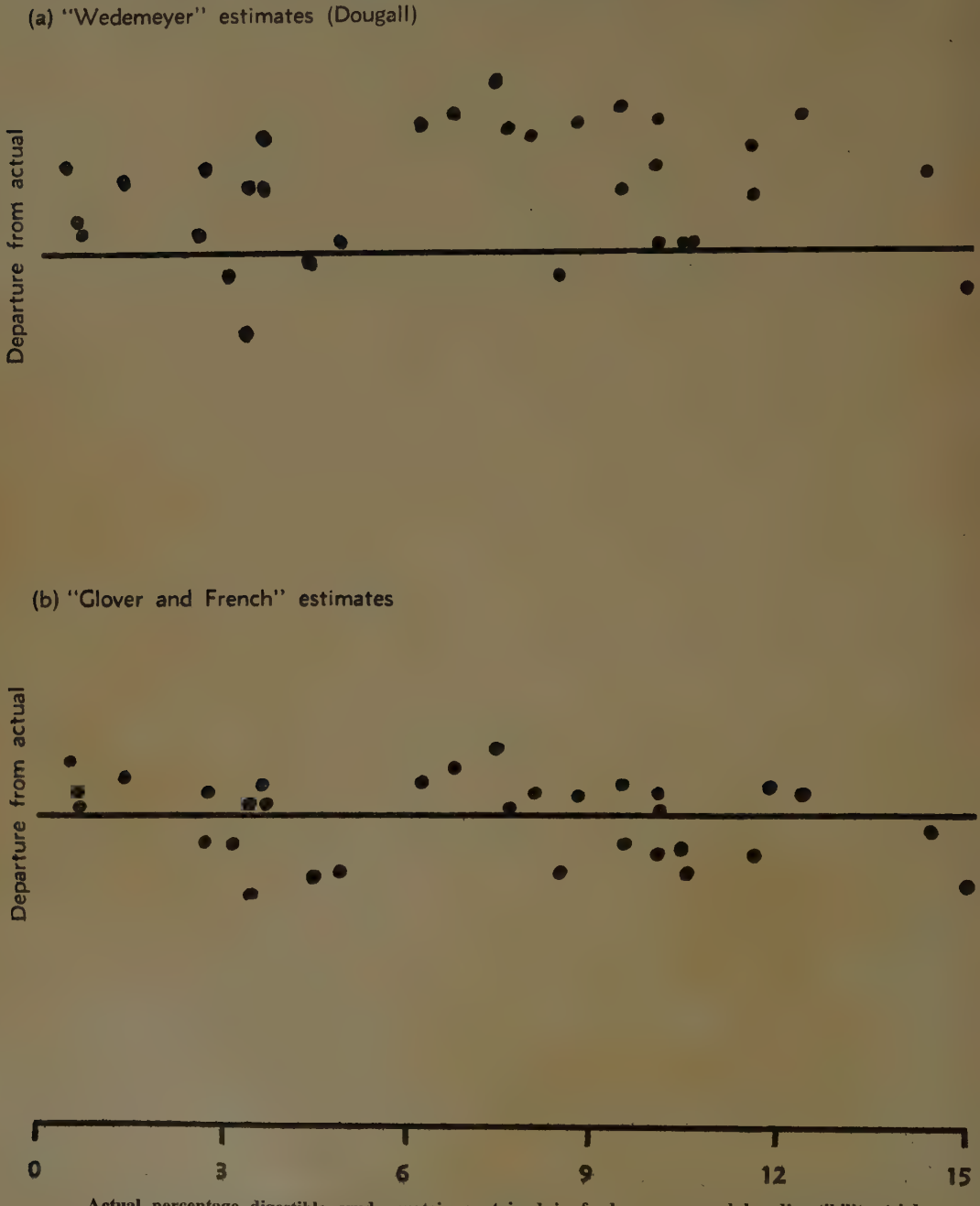


Fig. 2.—The relationships between crude protein and digestible crude protein (Glover and French) in the same Kenya feeding stuffs

feeds. On the other hand, if it is accepted that the Wedemeyer equation (1), which has been derived from 75 records for feeds of widely varying composition is representative of a general equation, then it may be used to obtain estimates of the digestible crude protein contained in the feeds used in recorded digestibility experiments, and these may be compared with the actual results. This was done by selecting at random 32 records of direct trials with cattle feeds as published by Schneider (1947). While most of these records were for grasses and hays, they also included some for silages, barley and oat grain, cotton-seed hulls, mangolds, cactus, kale and wheat straw. In recorded digestible crude protein content they ranged from 0.3 to 15 per cent. and in crude fibre content from 3 to 53 per cent. The estimates of digestible crude protein calculated from the Wedemeyer equation were found to be almost consistently higher than the actuals. Thus 27 out of the 32 were higher and only five slightly lower. This result is shown graphically in Fig. 3 (*a*), where the differences, higher or lower, are plotted at each level of digestible crude protein. The corresponding estimates from the Glover and French equation are shown in Fig. 3 (b). As might be expected, they are much closer to the actuals and are consistent in that the errors are reasonably evenly distributed above and below the line. This is reflected in the mean difference from actuals which, for the Wedemeyer equation, was 1.15 units, and for the Glover and French equation only 0.07 units. This difference proved to be significant to more than 1,000/1. There can be little doubt, therefore, that the Wedemeyer equation produces less satisfactory estimates of digestible crude protein than the Glover and French equation and, of the two, the latter is to be preferred.

Fig. 3.—Comparative estimates of digestible crude protein in 32 feeds from Schneider's data on cattle



SUMMARY

The Wedemeyer method of artificial digestion has been applied to a wide range of Kenya feeding stuffs. It has been found that the digestible crude protein contained in the dry matter of these feeds is related directly to their crude protein content. The equation: dig. P = 0.94 c.p. — 2.51, expresses this relationship.

This equation has been tested against the Glover and French equation, using both to estimate the results of recorded digestibility experiments. The Wedemeyer equation gave results which were almost consistently much too high, whereas the Glover and French equation gave consistent results which were in much closer agreement with the values actually recorded.

ACKNOWLEDGMENT

I desire to thank Mr. J. Glover of the East African Agriculture and Forestry Research Organization, Muguga, Kenya, for his advice and assistance in the preparation of this paper.

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REVIEW

ATOMIC ENERGY IN AGRICULTURE, by W. E. Dick, published by Butterworths Scientific Publications, London, 150 pp., 1957, price 18*s*.

This book, which is one of a series with the general title "Atoms for Peace", was written as a result of the international congress on the peaceful uses of atomic energy which was held at Geneva in August, 1955. Although the author has used the material presented as papers to the conference, he has led up to the recent advances in the use of atomic radiations by historical accounts of the work which preceded the present stage of the work. For example, in the chapter headed "Remaking Crop Plants with Radiation", he gives a summary of the work with X-rays and ultra-violet rays which enabled plant breeders to produce gene mutations before they could use atomic radiations. In fact, in this particular field of work atomic radiations merely provide an improved tool for the production of crop plant "sports" with special characters which may or may not be of economic importance.

Although atomic radiation is merely an improvement and not an initiation of the alteration of the hereditary characters of plants, the effects are so striking that dramatic changes in world agriculture can be forecast. Rust resistance has been developed in wheat by X-ray and atomic radiations, and a variety of groundnuts resistant to leaf-spot has been found among the innumerable mutants which resulted from irradiated seed. Improved varieties of barley have already been obtained by X-ray irradiation, and new runner beans, peas and mustard have also been produced. Fruit trees have been irradiated in order to produce "bud sports" with special characters, and the possibilities of rapidly producing improved varieties of crop plants are almost limitless. Genetic characters such as early ripening and drought resistance can also be produced, or strengthened, by irradiation, and the introduction of this technique into tropical plant-breeding is certain to have far-reaching results. It is interesting to recall that world starvation, which was predicted towards the end of last century, was staved off temporarily at least by the fixation of atmospheric nitrogen in the form of nitrogenous fertilizers: the production of new varieties by means of atomic radiation may make it possible to grow crops in areas which are now unsuitable for agriculture, and the present fears of world food shortage may prove to be unfounded.

The production of new varieties of crop plants is only one of the uses of atomic energy in agriculture. Pest control and food preservation are also of vital importance in world food supplies, and atomic radiation is providing rapid and striking advances in these branches of science. Apart from these spectacular results, which are of immediate economic importance, radioactive "tracers" are speeding up the fundamental studies in plant physiology and progress in this field will ultimately be of the utmost value in practical agriculture.

This book can be recommended to all who are interested in the future of agriculture. Although most of the work to date has been carried out in temperate climates with temperate crops, it is not difficult to see that the impact of the new techniques in tropical crop production, pest control, and food preservation would produce even more striking results than in the relatively high-yielding agricultural areas of the temperate zones. D.W.D.

ANNOTATED LIST OF INSECTS ASSOCIATED WITH THE SWEET POTATO (Ipomoea batatas)

By Walter M. Maitai, Department of Agriculture, Kenya

Observations made at the Coffee Research Station, Ruiru, Kenya
December, 1954–June, 1955

(*Received for publication on 19th November, 1957*)

PHYTOPHAGOUS INSECTS

COLEOPTERA

CASSIDIDAE (TORTOISE BEETLES)

Acrocassis gibbipennis Boh.—Larvae and adults feed on leaves. Not a serious pest and not frequently observed.

Acrocassis testaceicollis Thoms.—Larvae and adults feed on leaves. Damage not serious and not frequently observed.

Aspidomorpha areata Klug.—Larvae and adults feed on leaves. Damage not very serious but frequently observed.

Aspidomorpha concinna Wse.—Larvae and adults feed on leaves but do not do serious damage.

Aspidomorpha parummaculata Boh.—Larvae and adults feed on leaves. This insect did serious damage and is the most important cassid in this locality.

Aspidomorpha tecta Boh.—Larvae and adults feed on leaves. This species follows *A. parummaculata* in importance as a pest. Very frequently observed.

Laccoptera ferruginea Linell.—Larvae and adults feed on leaves. It was not often observed.

CURCULIONIDAE (WEEVILS)

Alcidodes dentipes Oliv.—The adults feed on growing points of stems. The larvae bore in stems, but tubers are not attacked.

Alcidodes leucogrammus Er.—Does similar damage to *A. dentipes* but of a less serious nature. Not so frequently observed as *A. dentipes* or *A. orientalis*.

Alcidodes orientalis Chev.—Adults feed on the bark and soft parts of the stems. Larvae bore in the stems and do serious damage.

Cylas puncticollis Boh.—Adults feed on leaves and softer parts of the stems. The larvae bore in the stems and tubers. This is by far the worst pest of sweet potato stems and tubers in this locality. It breeds rapidly and was very frequently observed.

Blosyrus sp.—Feeds on leaves. Seldom observed, and does very little damage.

HISPIDAE

Oncocephala montivaga Gest.—Larvae mine in the leaves. Infrequently observed, and does little damage.

HEMIPTERA

COCCIDAE (SCALE INSECTS, MEALY BUGS)

Dysmicoccus brevipes (Ckll.).—Found on underground parts of the plant. Uncommon.

Planococcus kenyae (Le Pelley).—Not a serious pest of this plant. Found only on aerial parts of the plant. Not frequently observed.

Pulvinaria sp.—Usually attacks the underground parts of the plant but can also be found on the aerial parts.

?*Trionymus* sp.—Found on underground parts of the plant. Common, probably does more damage than is realized.

COREIDAE (PLANT-SUCKING BUGS)

Acanthomia tomentosicollis Stal.—Nymphs and adults suck the juices of the leaves. The damage is not serious, but the insect was common.

Anoplocnemis curvipes Let. & Sev.—Nymphs and adults of this insect feed by sucking juices from the growing points. Damage not serious. Frequently seen.

Nezara viridula L.—Nymphs and adults feed on growing points. Not often observed: the damage not noticed.

LEPIDOPTERA

AGROTIDAE (NIGHT-FLYING MOTHS)

Melanephia tristis Snell.—Larvae feed on leaves only.

GELECHIIDAE

Brachmia convolvuli Wals.—Larvae feed on the leaves which they fold about them. Not a pest of importance.

SPHINGIDAE (HAWK MOTHS)

Herse convolvuli L.—Larvae feed on leaves. The defoliation can sometimes be severe but is not usually of great extent.

PTEROPHORIDAE (PLUME MOTHS)

Sp. *indet.*—The larvae feed on the leaves of sweet potatoes. Not a pest of importance.

LYONETIDAE

Bedellia sommulentella Zell.—Larvae mine in the leaves. Damage not severe, but more so than that done by the Hispid, *Oncocephala montivaga.*

THYSANOPTERA

THRIPIDAE (THRIPS)

Franklinothrips megalops (Trybom).—Not of importance. Possibly predaceous.

Scirtothrips sp.—Not a pest of importance. Very slight damage observed.

PARASITES

DIPTERA

TACHINIDAE

Sturmia atropivora R-D.—Primary parasite of the larvae of *H. convolvuli* (Sphingidae). Several individuals may emerge from one host larva.

Sturmia dilabida Villen.—Primary parasite of *H. convolvuli* and *Melanephia tristis* (Agrotidae). Behaves as do the other Tachinids above.

Sturmia zonata Curr.—Parasite of *Melanephia tristis,* but not as important as *S. dilabida.*

HYMENOPTERA

CHALCIDIDAE

Brachymeria sp.—Hyperparasite on *Sturmia* in *M. tristis.*

Brachymeria sp.—Parasite in the pupae of *Aspidomorpha areata, A. tecta, A. concinna, A. parummaculata.* Parasite status not known.

ENCYRTIDAE

Cheiloneurus cyanonotus Waterst.—A multiple parasite of the pupae of *Aspidomorpha areata, A tecta, A. concinna, Acrocassis gibbipennis* and *A. testacicollis.* Frequently observed.

Gen. nr. Paraphaenodiscus.—Parasite in ?*Trionymus* sp. Frequently observed. An important parasite of this coccid.

Genus et sp. *indet.*—Parasite of *Pulvinaria* sp. An important parasite of this insect. Very frequently observed.

EULOPHIDAE

Aprostocetus aspidiomorphae Ferr.—Parasite in eggs of *Aspidomorpha parummaculata.* This is by far the most frequently observed egg parasite of this insect.

Cirrospilus cinctiventris Ferr. — Parasite emerges from pupae of *Oncocephala montivaga* Gest.

Dimmockia sp. n.—Parasite of pupae of *O. montivaga* Gest.

ICHNEUMONIDAE

Gen. nr. Vologa.—Emerges from pupa of *Aspidomorpha areata* and *A. tecta.* Possibly a hyperparasite.

SCELIONIDAE

Microphanurus sp.—Egg parasite of *Harpactor segmentarius,* Germ.

Telenomus pyramus Nixon.—Egg parasite of *H. segmentarius.*

PREDATORS

HEMIPTERA

PENTATOMIDAE

Afrius figuratus Germ.—Predator on Cassid larvae on sweet potato. Very frequently observed. A predator of importance.

REDUVIIDAE

Harpactor segmentarius Germ.—Predator on Cassid larvae. Frequently observed. A predator of importance.

ACKNOWLEDGMENTS

Grateful acknowledgment is made to the Commonwealth Institute of Entomology for identifying many of these insects.

The Coccidae mentioned were examined by G. de Lotto at the Scott Agricultural Laboratories, to whom thanks are also due.

REVIEWS IN BRIEF

PROCEEDINGS OF THE THIRD BRITISH WEED CONTROL CONFERENCE, 1956, Vols. 1 and 2. Available from the Secretary, British Weed Control Council, 61 Curzon Street, London, W.1. 870 pp., Price £2.2.0, post free.

The texts of 83 papers are published in these two volumes, along with a record of the discussions. The Conference did not deal directly with weedkillers in the tropics, but the 19 papers which deal with the use and action of the phenoxybutyrics in controlling weeds of cereals and legumes are of interest to farmers in the highlands of East Africa.

BIBLIOGRAPHY OF PLANT PROTECTION, 1946–47, by J. Bärner, obtainable from Bibliothek der Biologischen Bundesanstalt für Land —und Forstwirtschaft, Königin-Luise-Strasse, Berlin-Dahlem 19, West Germany, 1957, 460 pp., no price stated.

This work is a continuation of the series started by Dr. Morstatt in 1921, and previous volumes, of which there are 24, cover the years 1914–45 and 1950–51. This volume contains over 13,800 references for 1946–47, and it is intended that further volumes will be published in order to bring the series up to date.

REPORT ON CHLOROPHORA by E. W. Jones, H.M. Stationery Office, 1957, 108 pp., price 14*s*.

Part I of this Colonial Research Publication gives the conditions under which *Chlorophora* (known as mvule in East Africa) grows in Kenya, Tanganyika, Nyasaland, Belgian Congo, and Nigeria, along with the history of attempts to plant it. Part II, the principal part of the Report, describes the biology of *Chlorophora,* including soil, nursery and planting techniques, diseases and pests, and plantation methods, and also suggests possibilities for future research.

INVESTIGATIONS INTO GRAIN STORAGE PROBLEMS IN NYASALAND, with special reference to maize, by K. F. Salmond, Colonial Research Publications No. 21, 1957, obtainable from H.M. Stationery Office, 49 pp., price 4*s*. 6*d*.

This is a technical report on storage conditions for maize, losses during storage, changes of moisture content in stored maize, arthropods associated with stored maize, and insecticidal treatment. Although the work was carried out in Nyasaland the results and recommendations will apply to other maize-growing areas.

A REPORT ON CACAO RESEARCH, 1955–56, published by the Imperial College of Tropical Agriculture, Trinidad, B.W.I., and 40 Norfolk Street, London, W.C.2, 1957, 60 pp., price 15*s*.

This report for the two years 1955 and 1956 contains 13 papers on the results of fundamental studies of the genetics, nutrition, and environment of the cocoa tree and the fermentation of the raw bean.

PROCEEDINGS OF THE BRITISH SOCIETY OF ANIMAL PRODUCTION, 1957, published for the Society by Oliver and Boyd, Edinburgh and London, 96 pp., price 15*s*.

The annual Proceedings of this Society has now taken its place as a scientific journal instead of its former classification as an "occasional publication". This issue contains nine papers, several of which are of practical interest to livestock producers.

MILLIONS STILL GO HUNGRY, by Food and Agriculture Organization of the United Nations, Rome, 102 pp., 1957, price 5*s*.

This is a review of the present position of food distribution throughout the world, and of the efforts of FAO during the past 12 years to alleviate world hunger. The views and experiences of many members of the FAO staff were obtained. particularly of those who had worked for FAO during all or most of the period.

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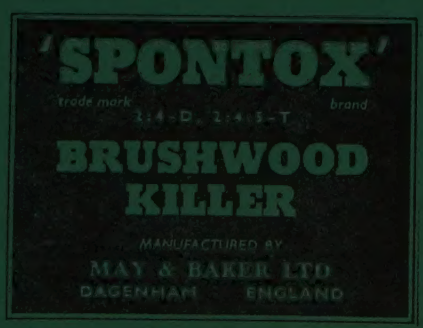

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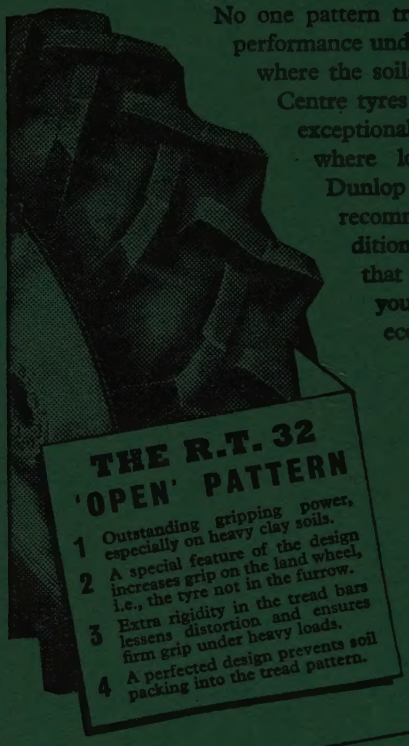

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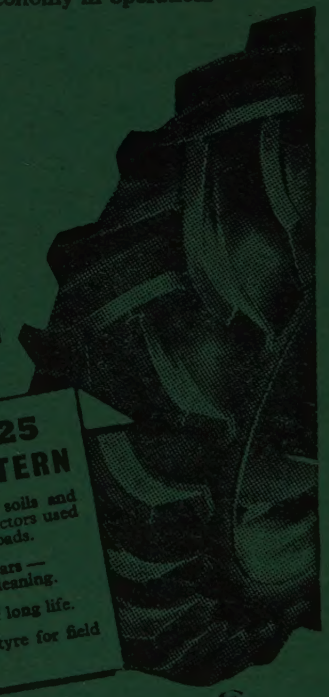

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